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## RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

PRELIMINARY INVESTIGATION OF THE STATIC LONGITUDINAL AND

LATERAL STABILITY CHARACTERISTICS OF A 0.05-SCALE

MODEL OF THE CONVAIR F2Y-1 AIRPLANE

AT HIGH SUBSONIC SPEEDS

TED NO. NACA DE 383

By Kenneth P. Spreemann and Albert G. Few, Jr.

Langley Aeronautical Laboratory  
Langley Field, Va.

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## PRELIMINARY INVESTIGATION OF THE STATIC LONGITUDINAL AND

## LATERAL STABILITY CHARACTERISTICS OF A 0.05-SCALE

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## SUMMARY

A preliminary investigation of the static longitudinal and lateral stability characteristics of a 0.05-scale model of the Convair F2Y-1 water-based fighter airplane was made in the Langley high-speed 7- by 10-foot tunnel. The investigation was made with and without wing fences over a Mach number range of 0.50 to 0.94. The maximum angle-of-attack range (obtained at the lower Mach numbers) was from about  $-2^{\circ}$  to  $25^{\circ}$ . Sideslip angles ranging from  $-4^{\circ}$  to  $12^{\circ}$  also were investigated.

For the basic model without fences, regions of longitudinal instability were found to exist at a lift coefficient of about 0.40 throughout the Mach number range investigated. In general, most of the fences employed delayed the instability of the model to considerably higher lift coefficients and angles of attack. The fences had little or no significant effects on the lift and drag characteristics except for a small increase in drag at zero angle of attack. The elevator effectiveness at zero lift for small settings and for the lower Mach numbers held up well through the lift-coefficient range; however, at Mach numbers of 0.92 and 0.94, rather large losses in effectiveness were indicated at the higher angles of attack.

The model was directionally stable up to  $21^{\circ}$  or  $23^{\circ}$  angle of attack but became highly unstable at higher angles. Up to a Mach number of 0.85, aileron effectiveness was rather constant up to  $20^{\circ}$  or  $22^{\circ}$  angle of attack; but above this Mach number, some reduction in effectiveness was evident

above about  $12^\circ$  or  $14^\circ$  angle of attack. The rudder effectiveness was almost constant throughout the Mach number and angle-of-attack range investigated.

## INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, National Advisory Committee for Aeronautics has conducted a preliminary investigation at high subsonic speeds of the static longitudinal and lateral stability characteristics of a 0.05-scale model of the Convair F2Y-1 water-based fighter airplane. The tests covered a Mach number range from 0.5 to 0.94 and corresponding Reynolds numbers, based on the wing mean aerodynamic chord, from  $3.3 \times 10^6$  to  $4.3 \times 10^6$ . The maximum angle-of-attack range (obtained at the lower Mach numbers) was from  $-2^\circ$  to  $25^\circ$ . Sideslip angles from  $-4^\circ$  to  $12^\circ$  also were investigated. The investigation included effects of various arrangements of wing fences and of rocket packages.

## COEFFICIENTS AND SYMBOLS

The stability system of axes used for the presentation of the data, together with an indication of the positive directions of forces, moments, and angles, are presented in figure 1. All moments are referred to the 30-percent-chord point of the mean aerodynamic chord.

$C_L$	lift coefficient,	$\frac{\text{Lift}}{qS_w}$
$C_D$	drag coefficient,	$\frac{\text{Drag}}{qS_w}$
$C_m$	pitching-moment coefficient,	$\frac{\text{Pitching moment}}{qS_w \bar{c}}$
$C_l$	rolling-moment coefficient,	$\frac{\text{Rolling moment}}{qS_w b}$
$C_n$	yawing-moment coefficient,	$\frac{\text{Yawing moment}}{qS_w b}$
$C_Y$	lateral-force coefficient,	$\frac{\text{Lateral force}}{qS_w}$

q	dynamic pressure, $\frac{\rho V^2}{2}$ , lb/sq ft
S	area, sq ft
$\bar{c}$	mean aerodynamic chord of wing, $\frac{2}{S_w} \int_0^{b/2} c^2 dy$ , 1.069 ft on model
c	local wing chord, parallel to plane of symmetry, ft
b	wing span, 1.76 ft on model
$\rho$	air density, slugs per cubic ft
V	free-stream velocity, ft/sec
P	static pressure, lb/sq ft
M	Mach number
R	Reynolds number of wing based on $\bar{c}$
$\alpha$	angle of attack of fuselage reference line, deg
$\beta$	angle of sideslip, deg
$\Lambda$	leading-edge sweep angle, deg
$\delta$	control surface deflection, deg
$C_{l_\beta} = \frac{\partial C_l}{\partial \beta}$	per deg
$C_{n_\beta} = \frac{\partial C_n}{\partial \beta}$	per deg
$C_{Y_\beta} = \frac{\partial C_Y}{\partial \beta}$	per deg
L/D	lift-drag ratio
Subscripts:	
o	free stream
w	wing

b	base of model fuselage
E	duct exit
e	elevon
r	rudder
max	maximum

#### MODEL DESIGNATIONS

B	fuselage
C	canopy
V	vertical fin
W	wing; W also used with following subscripts:
F <sub>1</sub>	fence 1
F <sub>2</sub>	fence 2
F <sub>3</sub>	fence 3
RP	rocket package

Combinations of the above designations that indicate the various configurations investigated are listed in table I.

#### MODEL AND APPARATUS

A drawing of the 0.05-scale model of the Convair F2Y-1 airplane employed in this investigation is presented in figure 2. Note that a small modification was made to the afterbody to accommodate the sting (shown in fig. 2). Details of the fences and fence positions tested are shown in figure 3. Included in figure 3 is a sketch of the rocket package tested on this model. Photographs of the various model configurations tested are presented in figure 4. A photograph of the basic model mounted on the sting in the Langley high-speed 7- by 10-foot tunnel is shown in figure 4(d). Presented in table II is a sketch of the probe positions employed in the duct exit.

The model was tested on the sting-type support system shown in figure 4(d). With this system, the model was remotely operated through

an angle-of-attack range of about  $-2^{\circ}$  to  $25^{\circ}$ . A strain-gage balance mounted inside the fuselage was used to measure the forces and moments of the model.

#### TESTS AND CORRECTIONS

The investigation was made in the Langley high-speed 7- by 10-foot tunnel over a Mach number range of 0.50 to 0.94 at angles of attack ranging from about  $-2^{\circ}$  to  $25^{\circ}$  and through a sideslip range from  $-4^{\circ}$  to  $12^{\circ}$ . The model caused the tunnel to choke above a corrected Mach number of about 0.97 at zero angle of attack, although partial choking conditions may have occurred in the high angle-of-attack range at a Mach number of 0.94.

Blockage corrections were determined by the method of reference 1 and were applied to the Mach numbers and dynamic pressures. Jet-boundary corrections, applied to the angle of attack and drag, were calculated by the method of reference 2. The angles of attack and sideslip have been corrected for deflection of the sting support system under load. The jet-boundary corrections to pitching moment were considered negligible and were not applied to the data. Corrections to the drag coefficients for buoyancy due to longitudinal pressure gradients were about 0.0007 to 0.0008 throughout the Mach number range investigated. These corrections were not applied to the data. No tare corrections were obtained.

The drag data have been corrected by adjusting the base pressure drag to a pressure at the base of the fuselage equal to free-stream static pressure. For this correction, the base pressure was determined by measuring the pressure inside the fuselage at a point about 9 inches forward of the base. The drag correction (base pressure drag coefficient  $C_{D_b}$ ) was calculated from the measured pressure data by the rela-

tion  $C_{D_b} = \frac{P_b - P_o}{q} \frac{S_b}{S_w}$ . Values of  $C_{D_b}$  for average test conditions are presented in figure 5. The corrected model drag data were obtained by adding the base pressure drag coefficient to the drag coefficient determined from the strain-gage measurements.

The mean Reynolds number variation with Mach number for the model of this investigation is presented in figure 6.

## RESULTS AND DISCUSSION

The data are presented in figures 7 to 26; a detailed listing of the data is given in table I. Presented in table II are the duct exit survey stations and velocity ratios for the BCW<sub>F1</sub>V configuration with  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ , and the duct full open. All configurations presented in the present paper were tested with ducts full open. Data for an elevon deflection of  $-20^\circ$  (presented in fig. 10) were obtained for a Mach number of 0.50 only because of limited tunnel time and the feeling that higher Mach numbers for this elevon deflection would be of little interest. The data indicated by dashed lines in figures 9 to 14 have been reproduced from figure 8 to facilitate analysis of these data. The slopes presented in figure 26 have been averaged over a lift-coefficient range of about 0 to 0.4. In order to expedite the publication of these data, only a brief analysis of the data is included herein.

## Longitudinal Stability Characteristics

Lift.- All configurations exhibited much the same maximum lift characteristics. (See parts (a) of figs. 8, 9, and 11 to 16 and fig. 10.)

The lift-curve slopes  $\frac{\partial C_L}{\partial \alpha}$  were practically unaffected by the addition of any of the fences (fig. 26). The trimmed lift-curve slope was about 10 to 15 percent lower than the untrimmed slope throughout the Mach number range investigated.

Drag.- The addition of any of the fences to the basic model (BCWV,  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ ) increased the drag coefficient at zero angle of attack  $C_{D_{\alpha=0}}$  about 0.001 to 0.002 throughout the Mach number range investigated. (See fig. 7.) An elevon deflection of  $-10^\circ$  resulted in an increase of 0.006 to 0.01 in  $C_{D_{\alpha=0}}$ ; whereas,  $-5^\circ$  deflection caused an increase of only about 0.001 throughout the Mach number range investigated.

The drag due to lift  $\frac{\partial C_D}{\partial C_L^2}$  was not greatly affected by the addition of fence 1 (see fig. 26). In the trimmed condition,  $\frac{\partial C_D}{\partial C_L^2}$  was increased about 20 to 30 percent up to  $M = 0.90$ . Above this Mach number, the trimmed model gave a sharp rise in drag due to lift.

Lift-drag ratios.- The addition of fence 1 to the basic model reduced the maximum lift-drag ratios by about 2 to 5 percent throughout the Mach number range investigated; however, at lift coefficients above that for  $(L/D)_{\max}$ , the effect of the fence was insignificant. Trimming the model at the assumed center-of-gravity location (0.30c) generally reduced the lift-drag ratios by from 15 to 20 percent over the Mach number range investigated. (See figs. 25 and 26.)

Pitching moment.- For the basic model without fences, regions of longitudinal instability were found to exist at a lift coefficient of about 0.40 throughout the Mach number range investigated. All of the fences employed, with the possible exception of fence 3, delayed the instability of the model to considerably higher lift coefficients and angles of attack (usually  $C_L \approx 0.2$  to  $0.4$  or  $6^\circ$  to  $8^\circ$  angle of attack). (See parts (d) and (e) of figs. 8 and 11 to 14.) However, the departures from linearity in the medium lift and angle-of-attack range still may be undesirable on the basis of dynamic-stability considerations. Fence 3 was the least effective in reducing the instability of the model, since pitch-up was indicated between lift coefficients of 0.3 to 0.4.

The fences employed on this model had little effect on the aerodynamic-center location as is illustrated in figure 26, wherein the addition of fence 1 (which is a typical example) gave practically no change in  $\frac{\partial C_m}{\partial C_L}$  throughout the Mach number range investigated.

Elevator effectiveness.- The results obtained for various elevator settings (figs. 8 and 9) indicate that the elevator effectiveness  $\left(\frac{\partial C_m}{\partial \delta_e}\right)_{C_L=0}$  (fig. 24) for small settings and for the lower Mach numbers held up well through the lift-coefficient range. At Mach number of 0.92 and 0.94, however, quite a large loss in effectiveness was indicated at high angles of attack. Although no serious loss was indicated at trim conditions for the assumed center-of-gravity location, it is possible that some impairment in maneuverability may result at the highest Mach numbers. At zero lift, the effectiveness parameter  $\frac{\partial C_m}{\partial \delta_e}$  for small deflections increased in magnitude from -0.0051 to -0.0064 as the Mach number increased from 0.50 to 0.90 but then decreased to -0.0057 at  $M = 0.94$ . (See fig. 24.) In assessing the elevator effectiveness, it should be noted that some flexibility in the elevator restraining members did exist; however, comparisons of the present data with additional data (not presented in this paper) obtained with the elevator locked indicate that the effects of flexibility were extremely small.

### Lateral Stability Characteristics

Lateral stability.- Within the ranges of test variables for which comparable data were obtained, there were only small changes in the lateral stability characteristics of the model with the addition of fence 1. With fence 1 installed, the model showed no instabilities in sideslip at  $0^\circ$  and  $12^\circ$  angle of attack; but at  $24^\circ$  angle of attack in the low Mach number range, large directional instabilities were encountered. (See fig. 18.) It should be noted that  $24^\circ$  angle of attack is at or above the maximum lift and consequently flow instability would be expected. The lateral-stability-parameter data presented in figure 19 show that the model with fence 1 became unstable at  $23^\circ$  and  $21^\circ$  angle of attack or at  $C_L = 0.8$  and  $0.85$  for Mach numbers of  $0.50$  and  $0.85$ , respectively. Note that these data were taken from the slopes between two series of tests made at  $14^\circ$  sideslip and, therefore, would not indicate nonlinearities that exist in the high angle-of-attack range between these two sideslip angles.

Comparison of figures 18 and 21 indicates that the tail contribution to the directional stability  $C_{n\beta}$  of the model at  $0^\circ$  and  $12^\circ$  angle of attack was increased from approximately  $0.0023$  at  $M = 0.50$  to  $0.0029$  at  $M = 0.92$ .

Aileron and rudder effectiveness.- The results of deflecting the left aileron to  $-10^\circ$  are presented in figure 22 for the model with fence 1 installed. Up to a Mach number of  $0.85$ , aileron effectiveness was rather constant up to  $20^\circ$  or  $22^\circ$  angle of attack; but above this Mach number, some reduction in effectiveness was evident above about  $12^\circ$  or  $14^\circ$  angle of attack.

The effects of a rudder deflection of  $10^\circ$  are presented in figure 23 and these data indicate almost constant rudder effectiveness throughout the Mach number and angle-of-attack range investigated.

### CONCLUSIONS

A preliminary investigation to determine the static longitudinal and lateral stability characteristics, with and without wing fences, of a  $0.05$ -scale model of the Convair F2Y-1 water-based fighter airplane at high subsonic speeds indicates the following conclusions:

(1) For the basic model without fences, regions of longitudinal instability were found to exist at a lift coefficient of about  $0.40$  throughout the Mach number range investigated.

(2) Most of the fences employed in this investigation delayed the longitudinal instability of the model to considerably higher lift coefficients and angles of attack.

(3) The fences had little or no significant effects on the lift and drag characteristics except for a small increase in drag at zero angle of attack.

(4) Deflecting the elevators to provide longitudinal trim reduced the maximum lift-drag ratios about 15 to 20 percent and increased the drag due to lift about 20 to 40 percent throughout the Mach number range investigated.

(5) The elevator effectiveness at zero lift for small settings and for the lower Mach numbers held up well through the lift-coefficient range; however, at Mach numbers of 0.92 and 0.94, quite large losses in effectiveness were indicated at the high angles of attack.

(6) The model was directionally stable up to  $21^\circ$  or  $23^\circ$  angle of attack, but became highly unstable at higher angles.

(7) Up to a Mach number of 0.85, the aileron effectiveness was almost constant up to  $20^\circ$  or  $22^\circ$  angle of attack, but above this Mach number some reduction in effectiveness was evident above about  $12^\circ$  or  $14^\circ$  angle of attack.

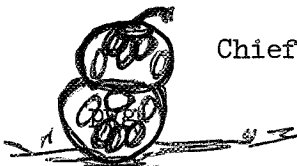
(8) The rudder effectiveness was almost constant throughout the Mach number and angle-of-attack range investigated.

Langley Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Langley Field, Va., December 30, 1953.

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## REFERENCES

1. Herriot, John G.: Blockage Corrections for Three-Dimensional-Flow Closed-Throat Wind Tunnels, With Consideration of the Effect of Compressibility. NACA Rep. 995, 1950. (Supersedes NACA RM A7B28.)
2. Gillis, Clarence L., Polhamus, Edward C., and Gray, Joseph L., Jr.: Charts for Determining Jet-Boundary Corrections for Complete Models in 7- by 10-Foot Closed Rectangular Wind Tunnels. NACA WR L-123, 1945. (Formerly NACA ARR L5G31.)

TABLE I.- INDEX OF FIGURES PRESENTING DATA

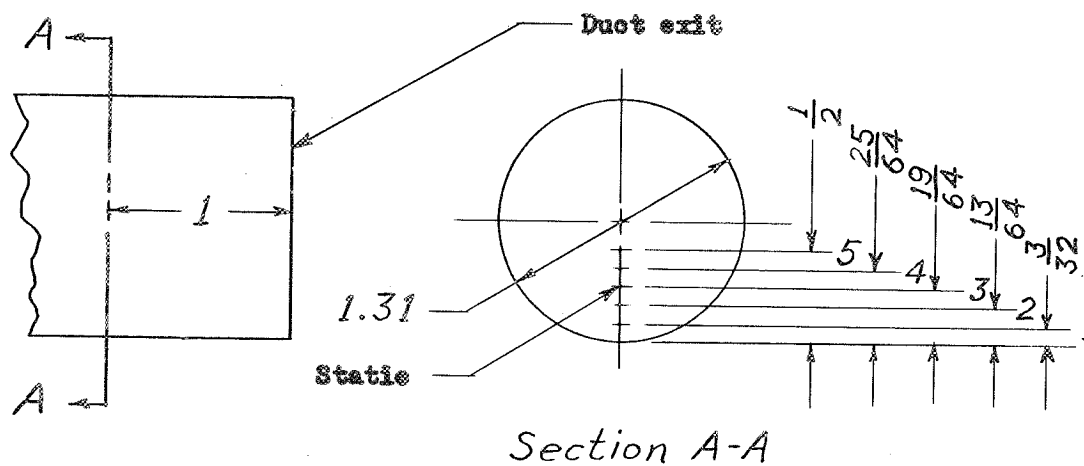
Figure	Configuration	$\delta_e$ , deg		$\delta_r$ , deg	Data presented
		Right	Left		
7	BC	0	0	--	Drag at $\alpha = 0^\circ$
	BCW <sub>F1</sub>	0	0	--	
	BCWV	0	0	0	
	BCW <sub>F1</sub> V	0	0	0	
	BCW <sub>F2</sub> V	0	0	0	
	BCW <sub>F3</sub> V	0	0	0	
	BCW <sub>F2+3</sub> V	0	0	0	
	BCW <sub>F1</sub> +RPV	0	0	0	
	BCW <sub>F1</sub> V	0	0	0	
	BCW <sub>F1</sub> V	-5	-5	0	
	BCW <sub>F1</sub> V	-10	-10	0	
8	BCWV	0	0	0	Basic longitudinal
	BCW <sub>F1</sub> V	0	0	0	
9	BCW <sub>F1</sub> V	0	0	0	Basic longitudinal
	BCW <sub>F1</sub> V	-5	-5	0	
	BCW <sub>F1</sub> V	-10	-10	0	
10	BCW <sub>F1</sub> V	0	0	0	Basic longitudinal
	BCW <sub>F1</sub> V	-20	-20	0	
11	BCWV	0	0	0	Basic longitudinal
	BCW <sub>F2</sub> V	0	0	0	
12	BCWV	0	0	0	Basic longitudinal
	BCW <sub>F3</sub> V	0	0	0	
13	BCWV	0	0	0	Basic longitudinal
	BCW <sub>F2+3</sub> V	0	0	0	

TABLE I. - INDEX OF FIGURES PRESENTING DATA - CONCLUDED

Figure	Configuration	$\delta_e$ , deg		$\delta_r$ , deg	Data presented
		Right	Left		
14	BCWV	0	0	0	Basic longitudinal
	$BCW_{F_1+RPV}$	0	0	0	
15	$BCW_{F_1}V$	0	-10	0	Basic longitudinal
16	$BCW_{F_1}V$	0	0	10	Basic longitudinal
17	BCWV	0	0	0	Basic lateral
18	$BCW_{F_1}V$	0	0	0	Basic lateral
19	$BCW_{F_1}V$	0	0	0	Lateral stability
20	$BCW_{F_1+RPV}$	0	0	0	Basic lateral
21	$BCW_{F_1}$	0	0	--	Basic lateral
22	$BCW_{F_1}V$	0	-10	0	Basic lateral
	$BCW_{F_1}V$	0	0	0	
23	$BCW_{F_1}V$	0	0	10	Basic lateral
	$BCW_{F_1}V$	0	0	0	
24	$BCW_{F_1}V$	0	0	0	Elevator effectiveness
25	BCWV	0	0	0	L/D
	$BCW_{F_1}V$	0	0	0	
26	BCWV	0	0	0	Summary
	$BCW_{F_1}V$	0	0	0	

TABLE II

## DUCT EXIT SURVEY STATIONS AND VELOCITY RATIOS

(Configuration  $BCW_{F1}V$ ;  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ )

M	$V_o$	$V_E/V_o$			
		Tube number			
		1	2	4	5
0.50	510	0.508	0.628	---	0.668
.70	774	.396	.488	---	.523
.85	926	.354	.432	0.477	.505
.90	972	.349	.436	.496	.524
.92	990	.348	.436	.501	.528
.94	1002	.339	.427	.494	.512

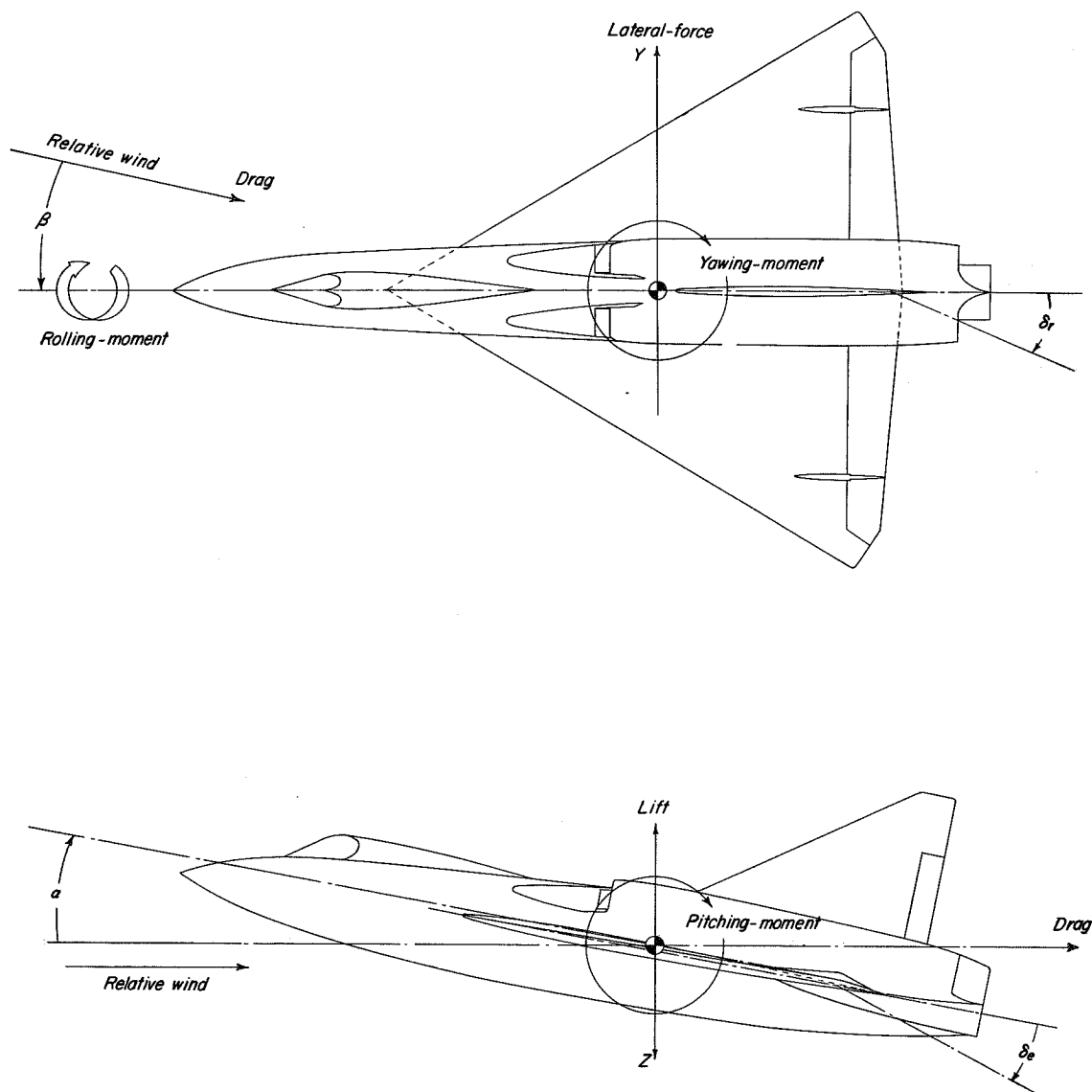
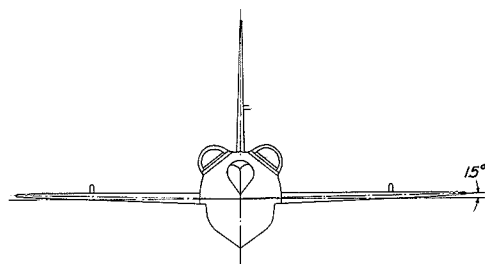


Figure 1.- System of axes used. Positive direction of forces, moments, and angles is indicated by arrows.



*Wing*

<i>Sweep, A, deg</i>	60
<i>Area sq ft</i>	142
<i>Aspect ratio</i>	218
<i>Span, ft</i>	176
<i>Mean aerodynamic chord, ft</i>	10.69
<i>Incidence, deg</i>	0
<i>Dihedral, deg</i>	1.5
<i>Airfoil section parallel to free stream</i>	
<i>Root</i>	NACA 65 - 003.3
<i>Tip</i>	NACA 65 - 004
<i>Vertical tail</i>	
<i>Sweep, deg, A</i>	56
<i>Area sq ft</i>	200
<i>Aspect ratio</i>	10

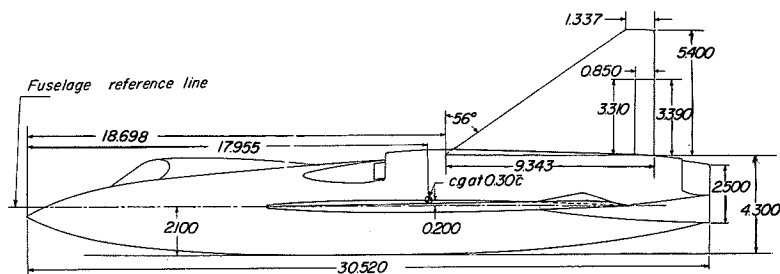
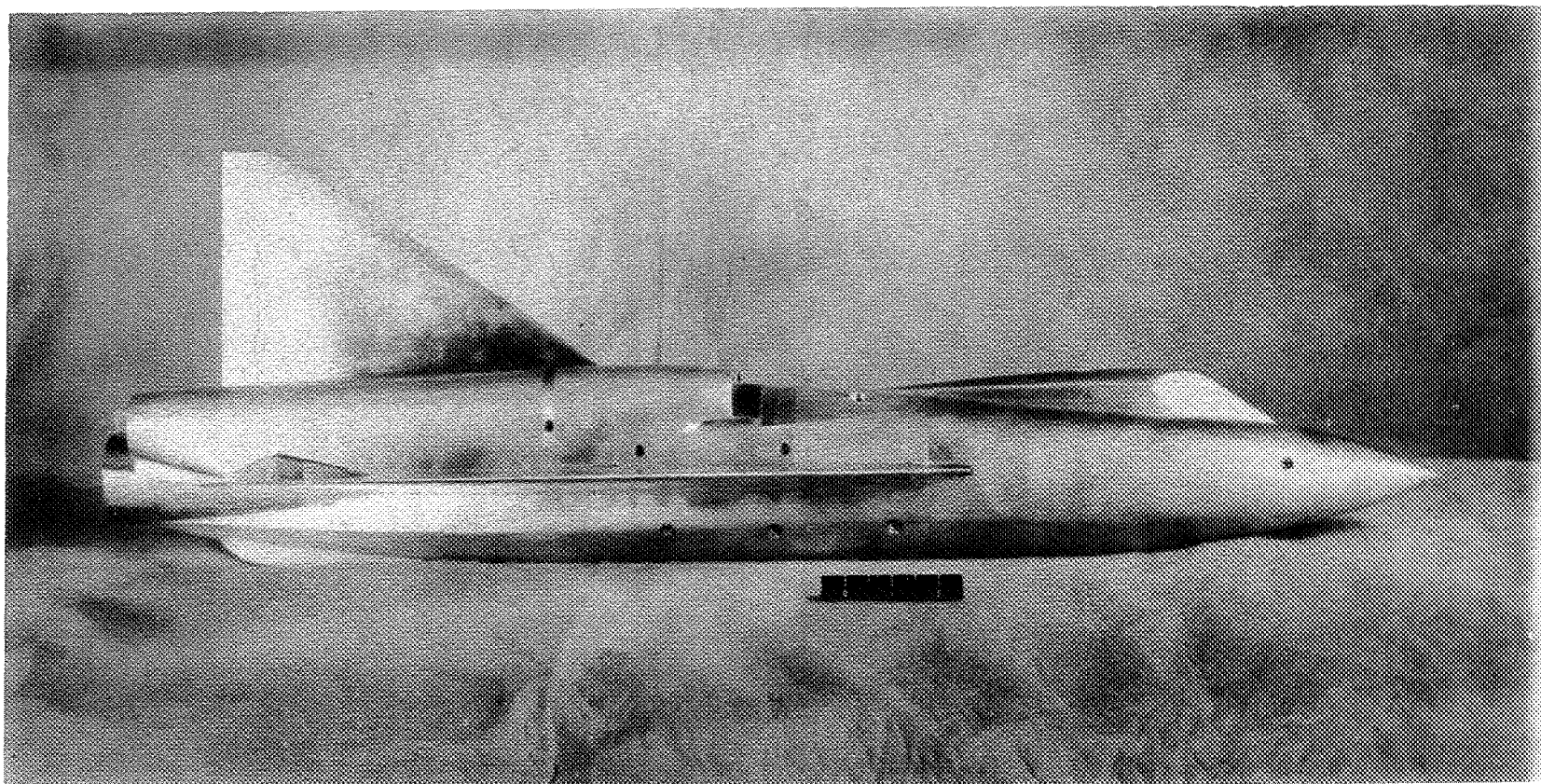


Figure 2.- General arrangement of test model. All dimensions are in inches.

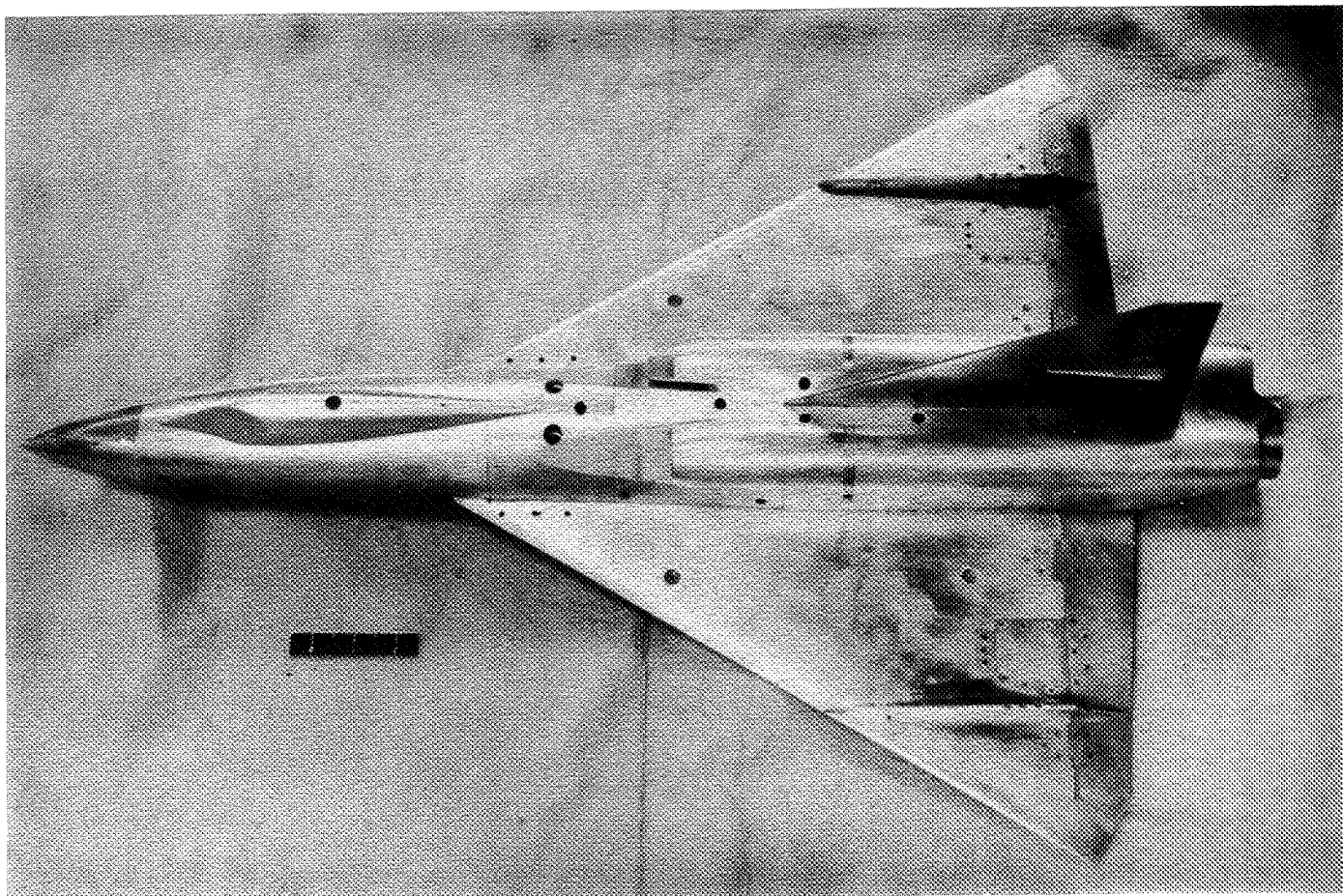
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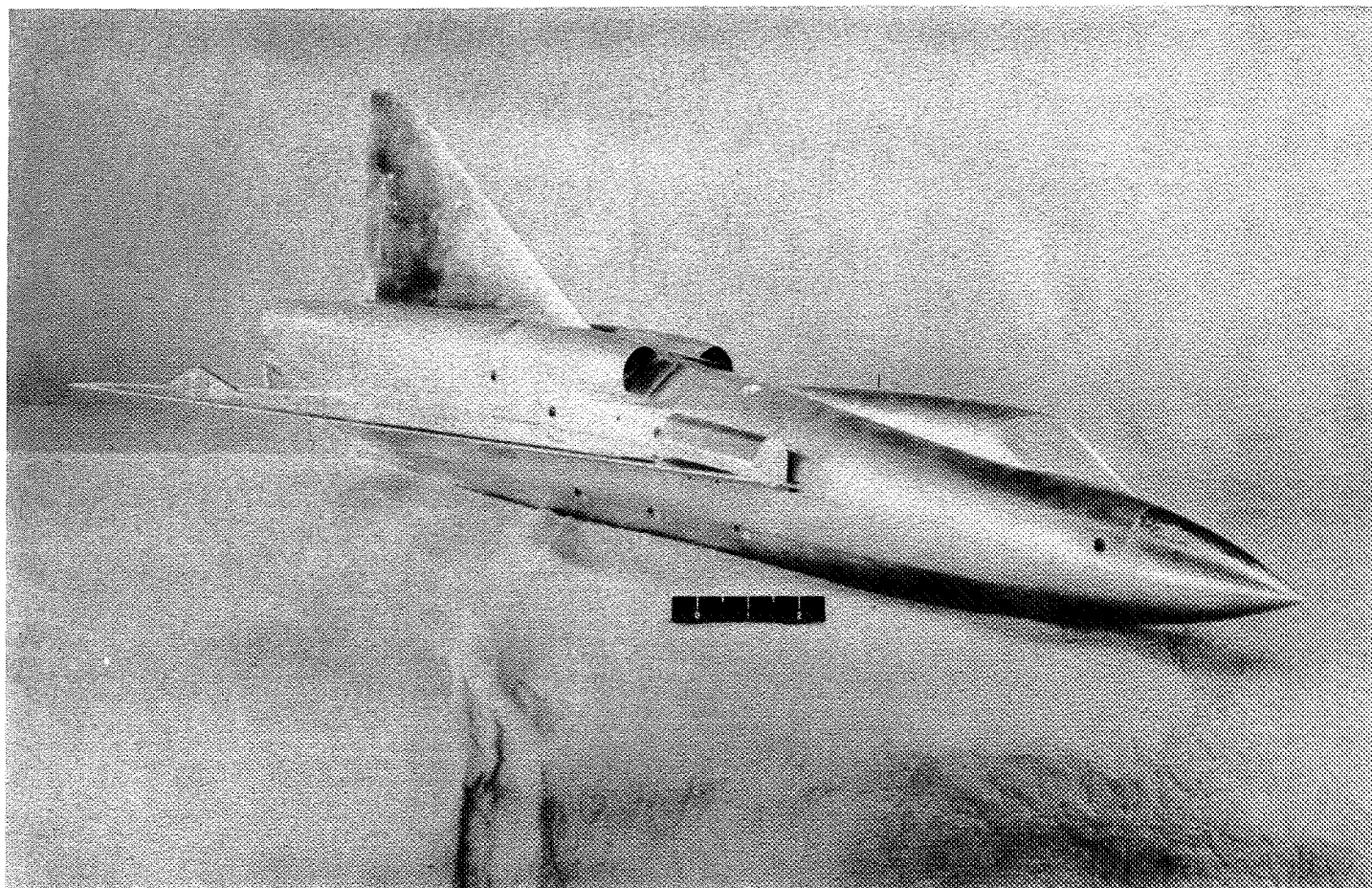
(a) Configuration BCWV;  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ . L-78678

Figure 4.- Photographs of test model.



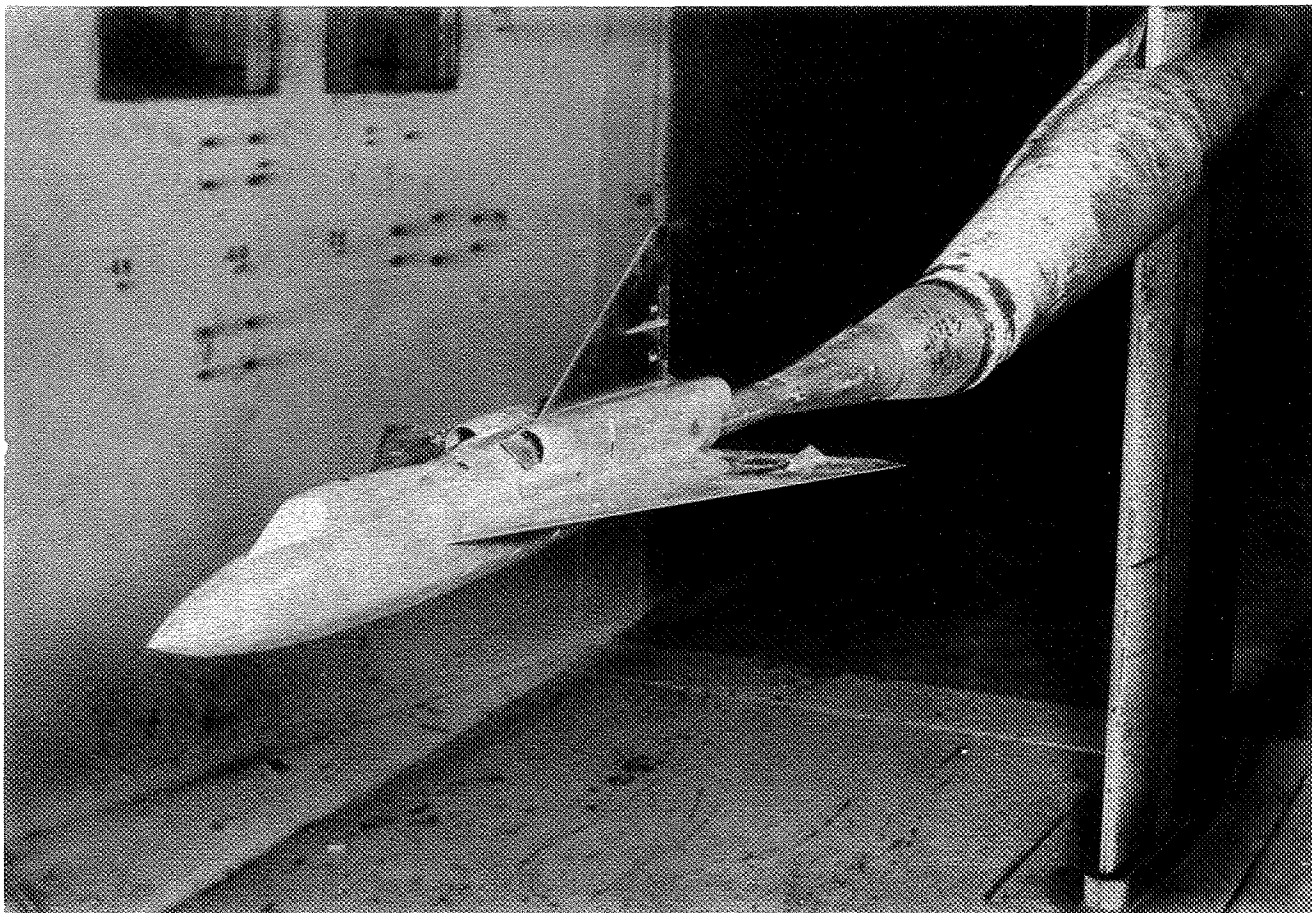
(b) Configuration  $BCW_{F_1} V$ ;  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ . L-78681

Figure 4.- Continued.



(c) Configuration  $BCW_{RPV}$ ;  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ . L-78680

Figure 4.- Continued.



L-78683

(d) Configuration BCWV;  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ , mounted on  
sting in Langley high-speed 7- by 10-foot tunnel.

Figure 4.- Concluded.

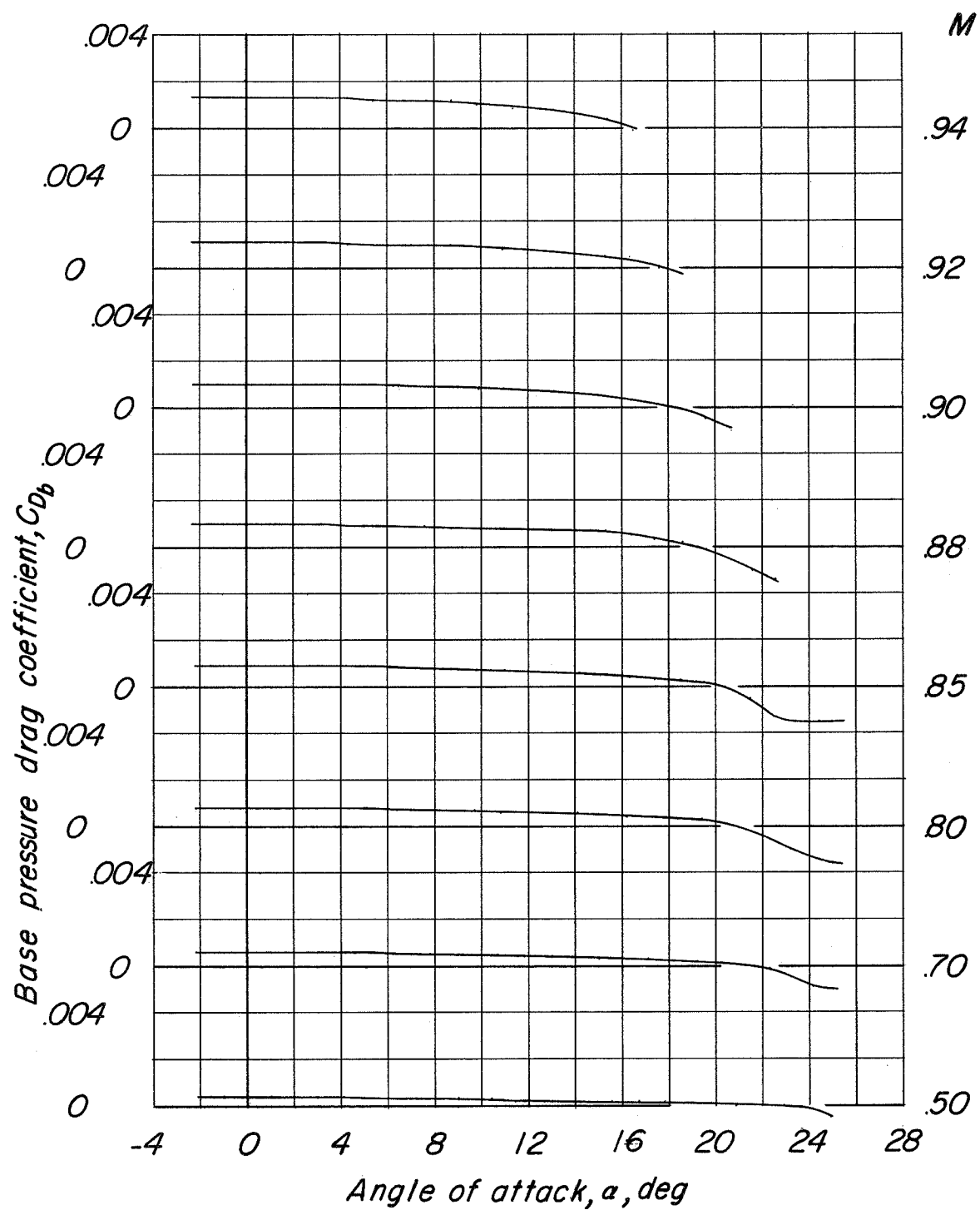


Figure 5.- Variation of base pressure drag coefficient with angle of attack and test Mach number.

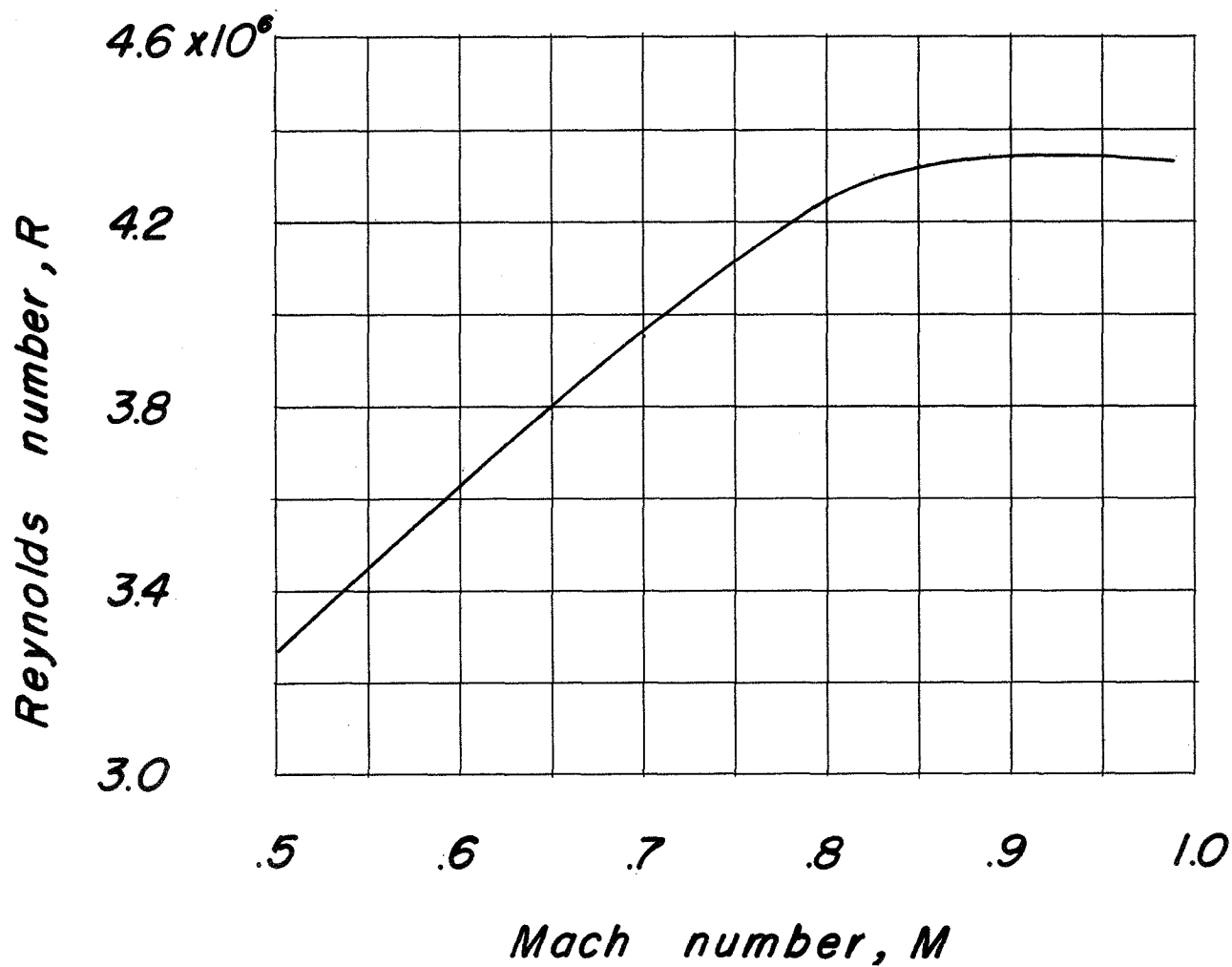


Figure 6.- Variation of test Reynolds number with Mach number based on wing mean aerodynamic chord.

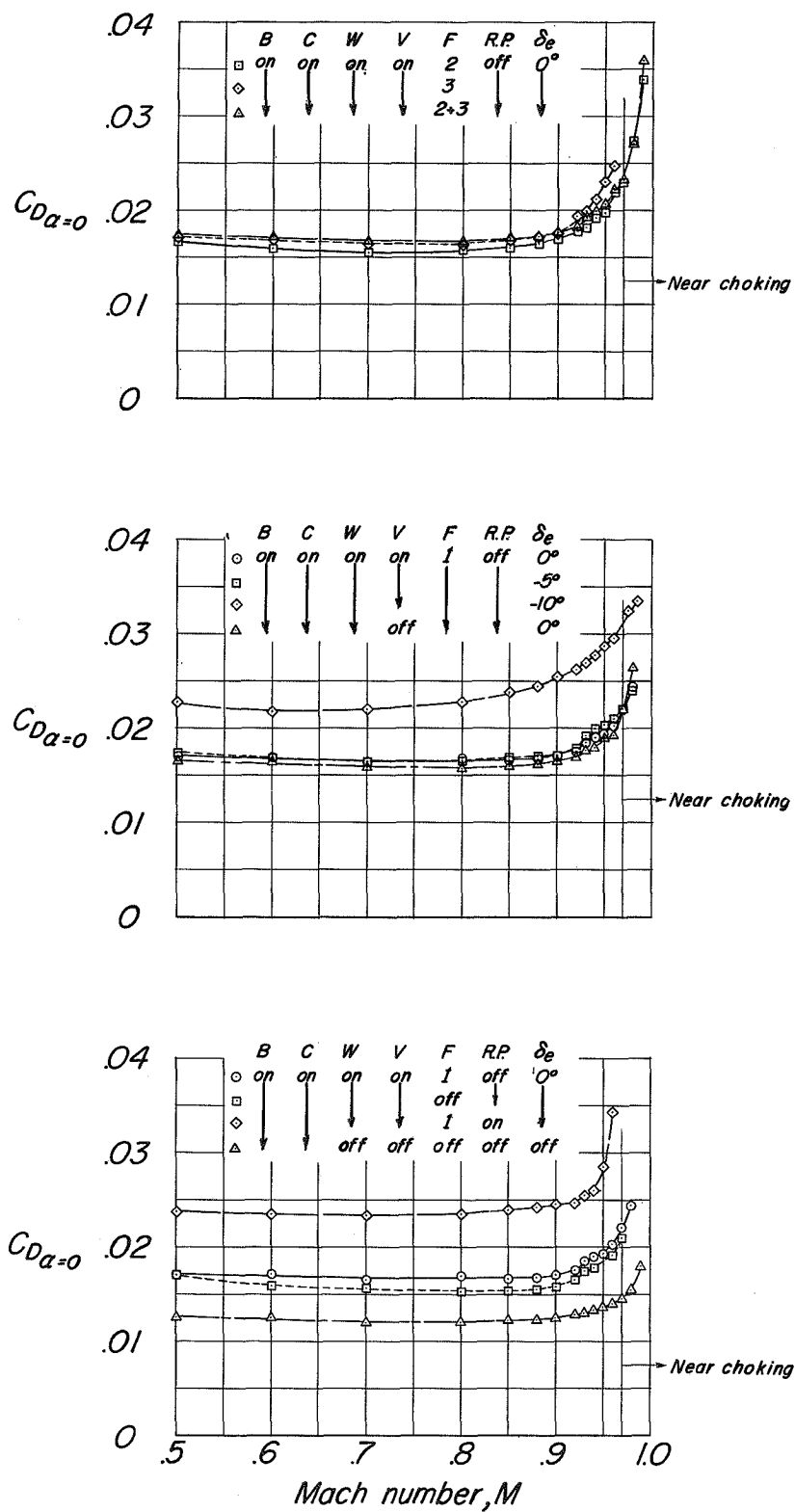


Figure 7.- Drag at zero angle of attack for 10 configurations investigated.

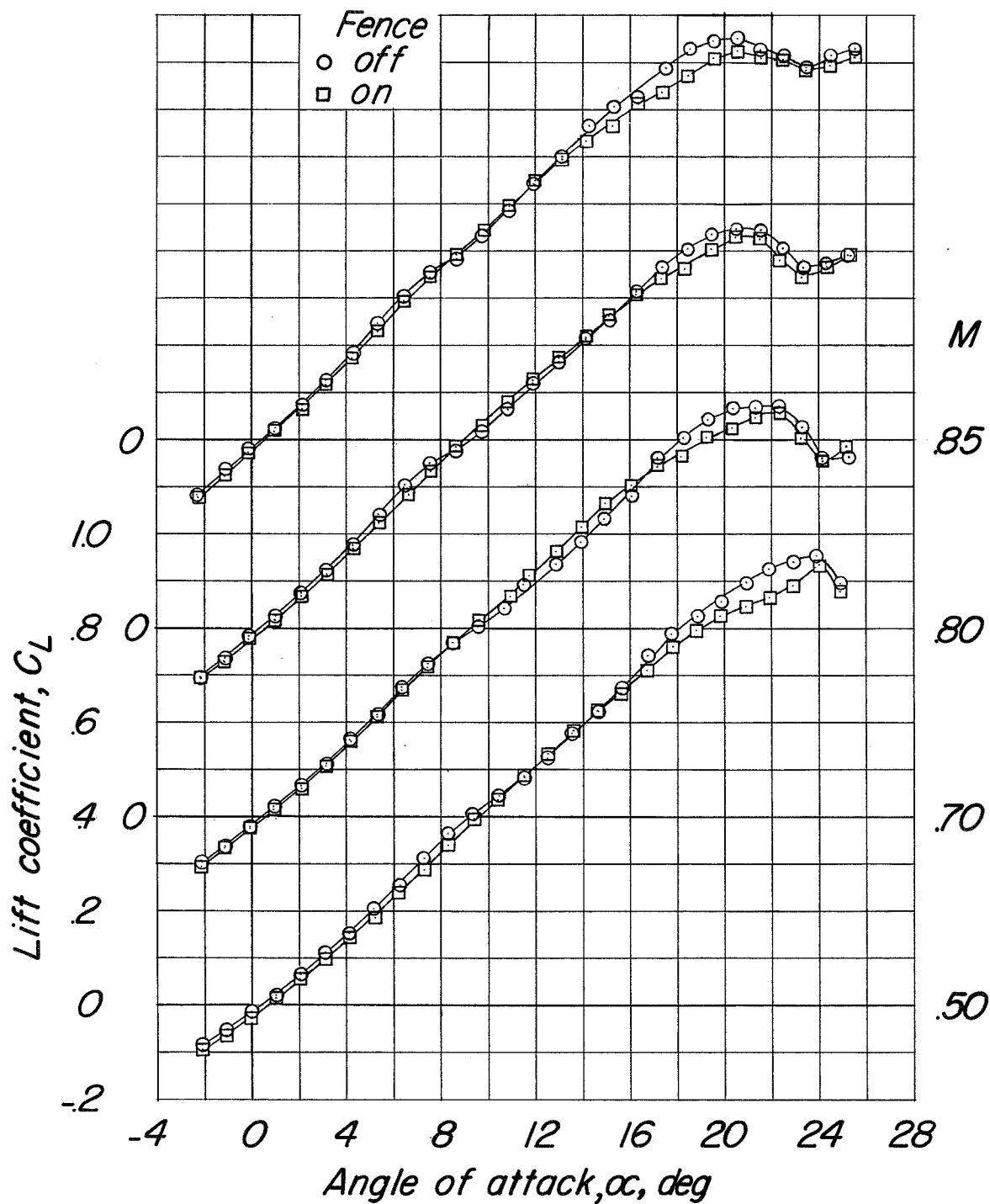
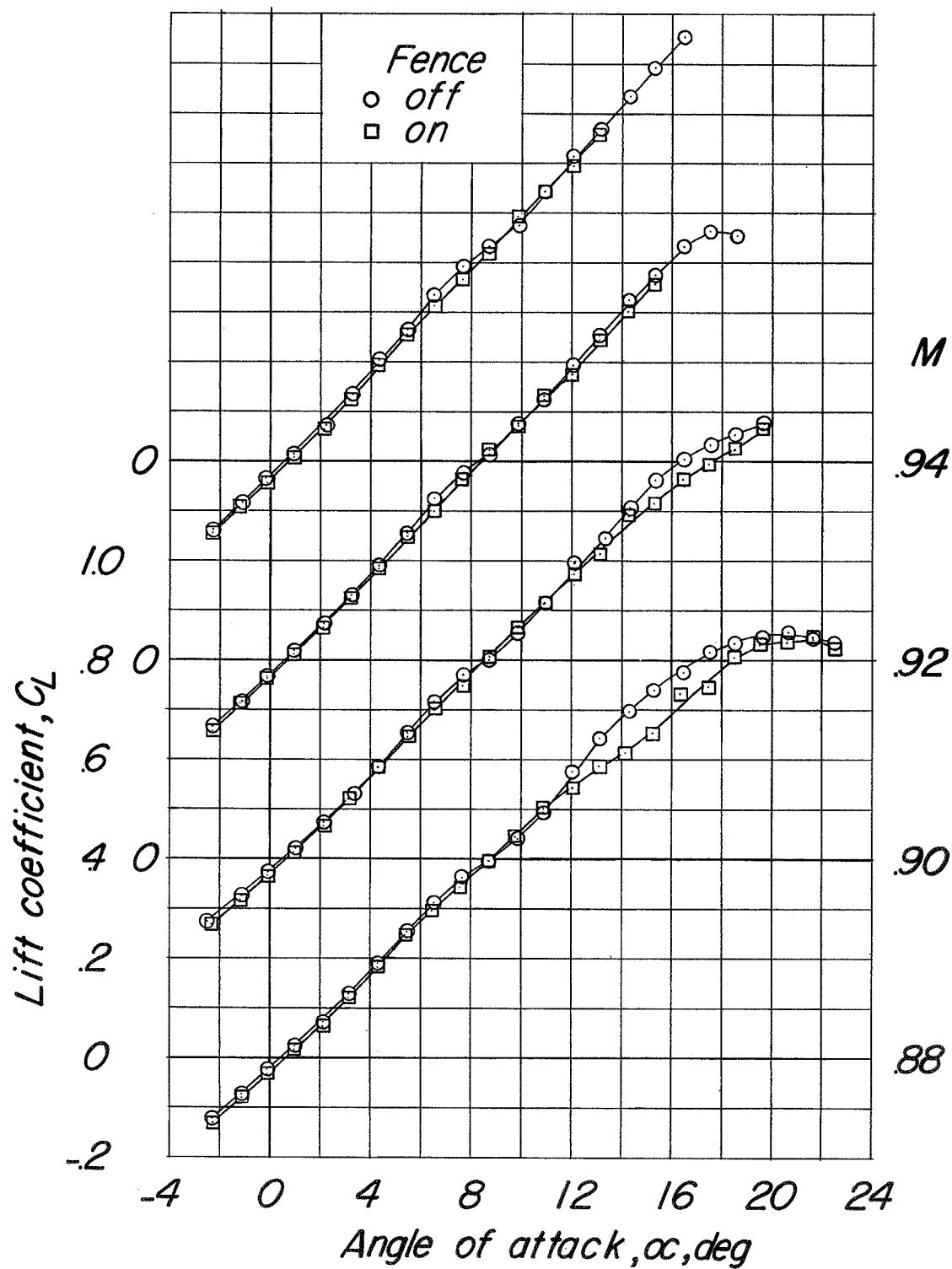
(a)  $C_L$  against  $\alpha$ .

Figure 8.- Basic longitudinal characteristics for configuration BCWV,  
 $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ , with and without fence 1.



(a) Concluded.

Figure 8.- Continued.

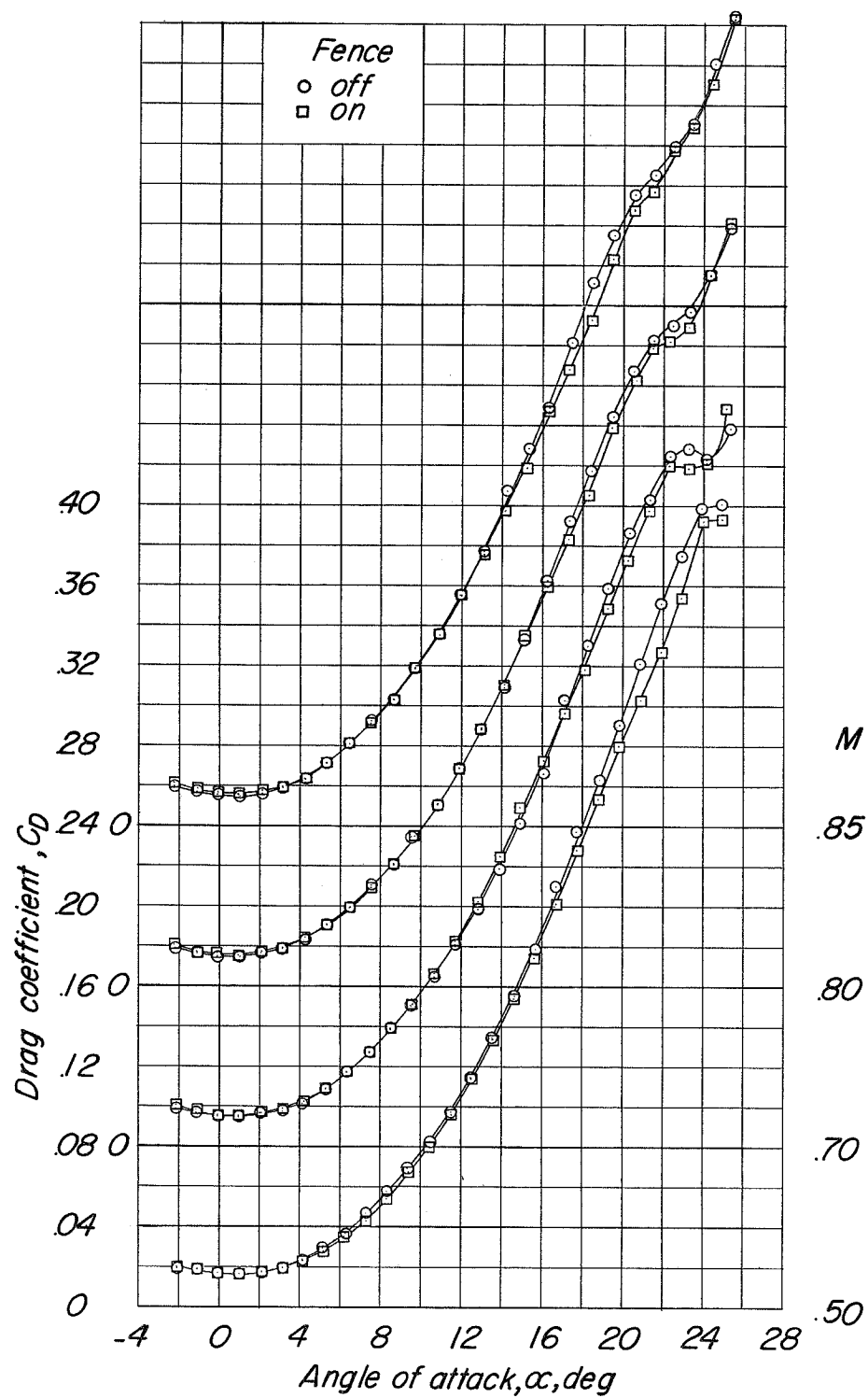
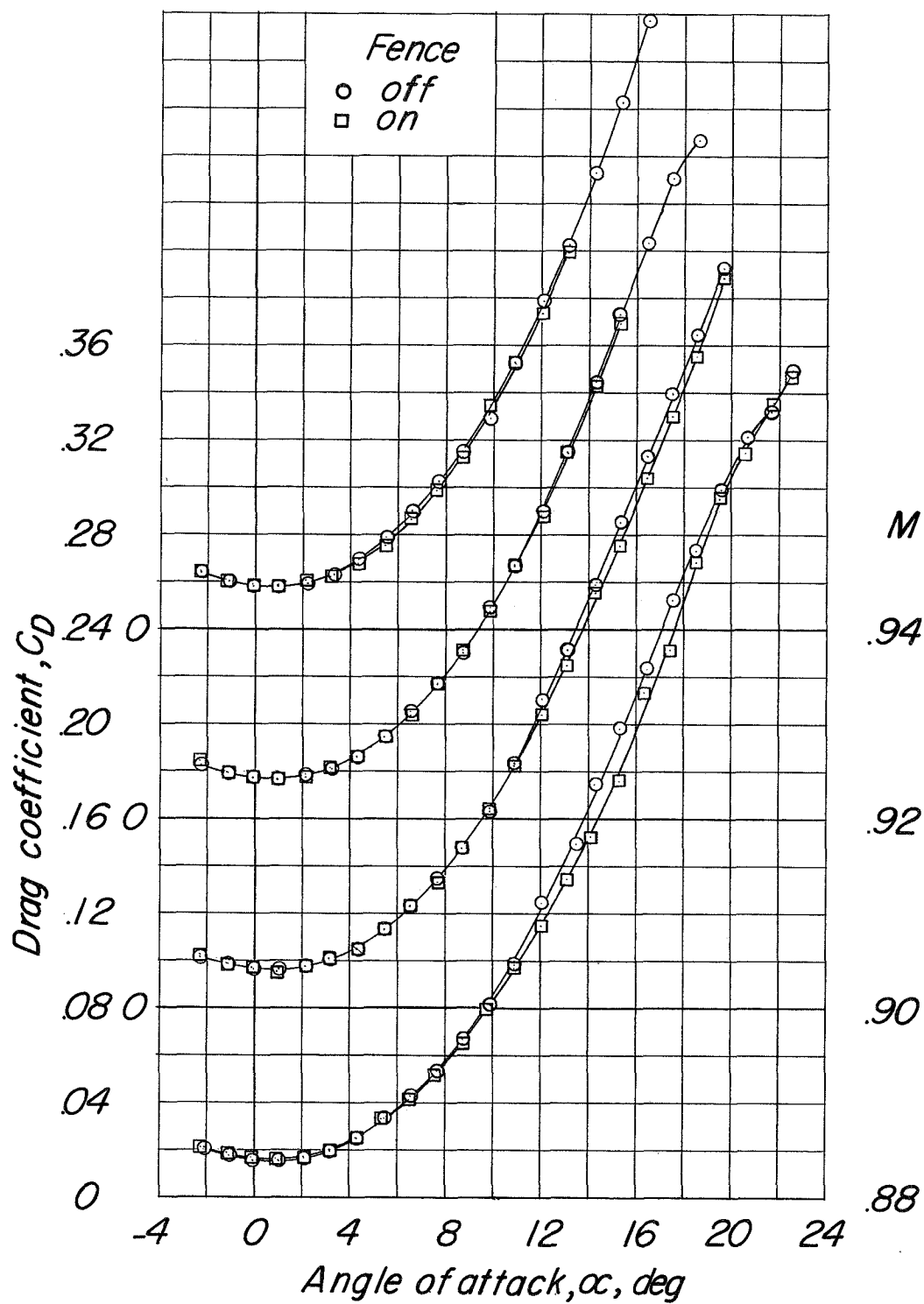
(b)  $C_D$  against  $\alpha$ .

Figure 8.- Continued.



(b) Concluded.

Figure 8.- Continued.

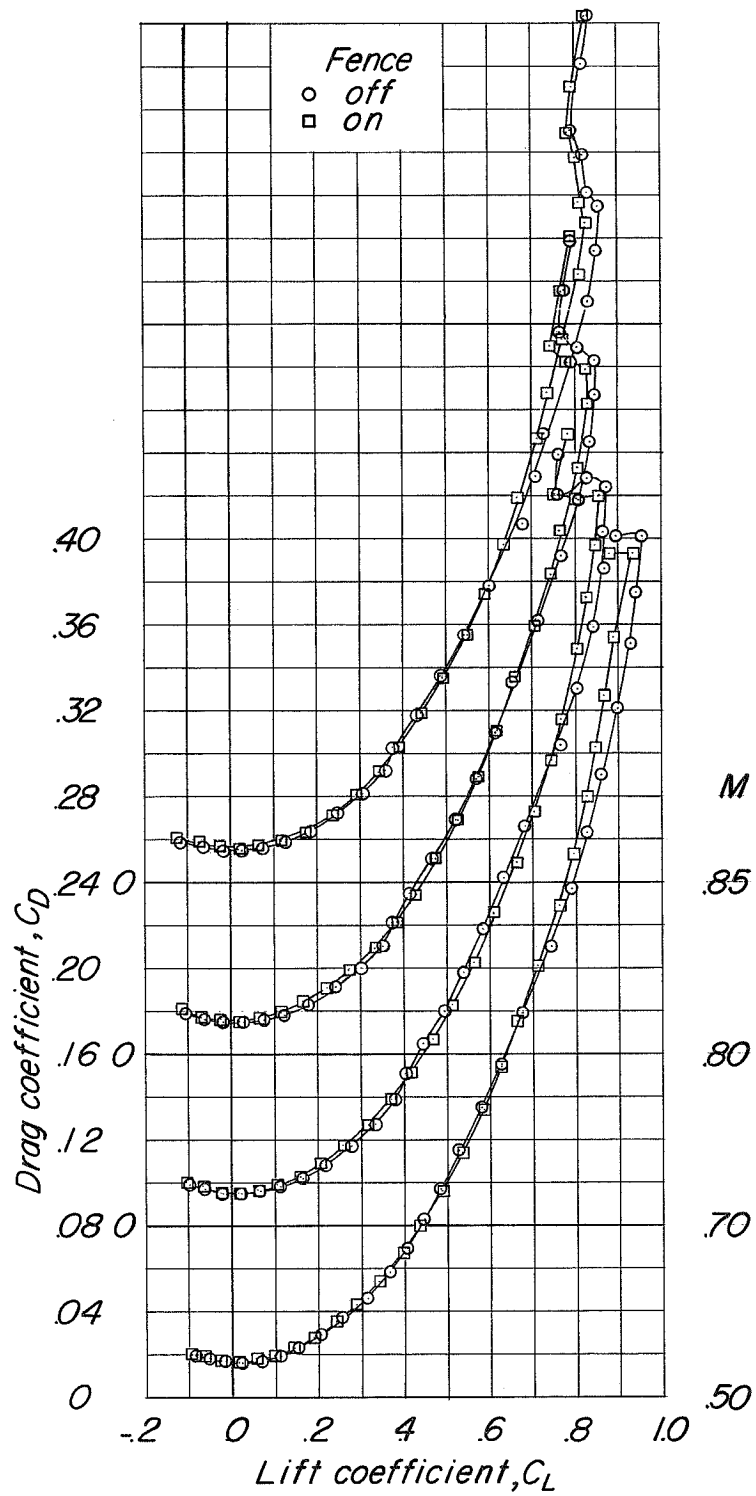
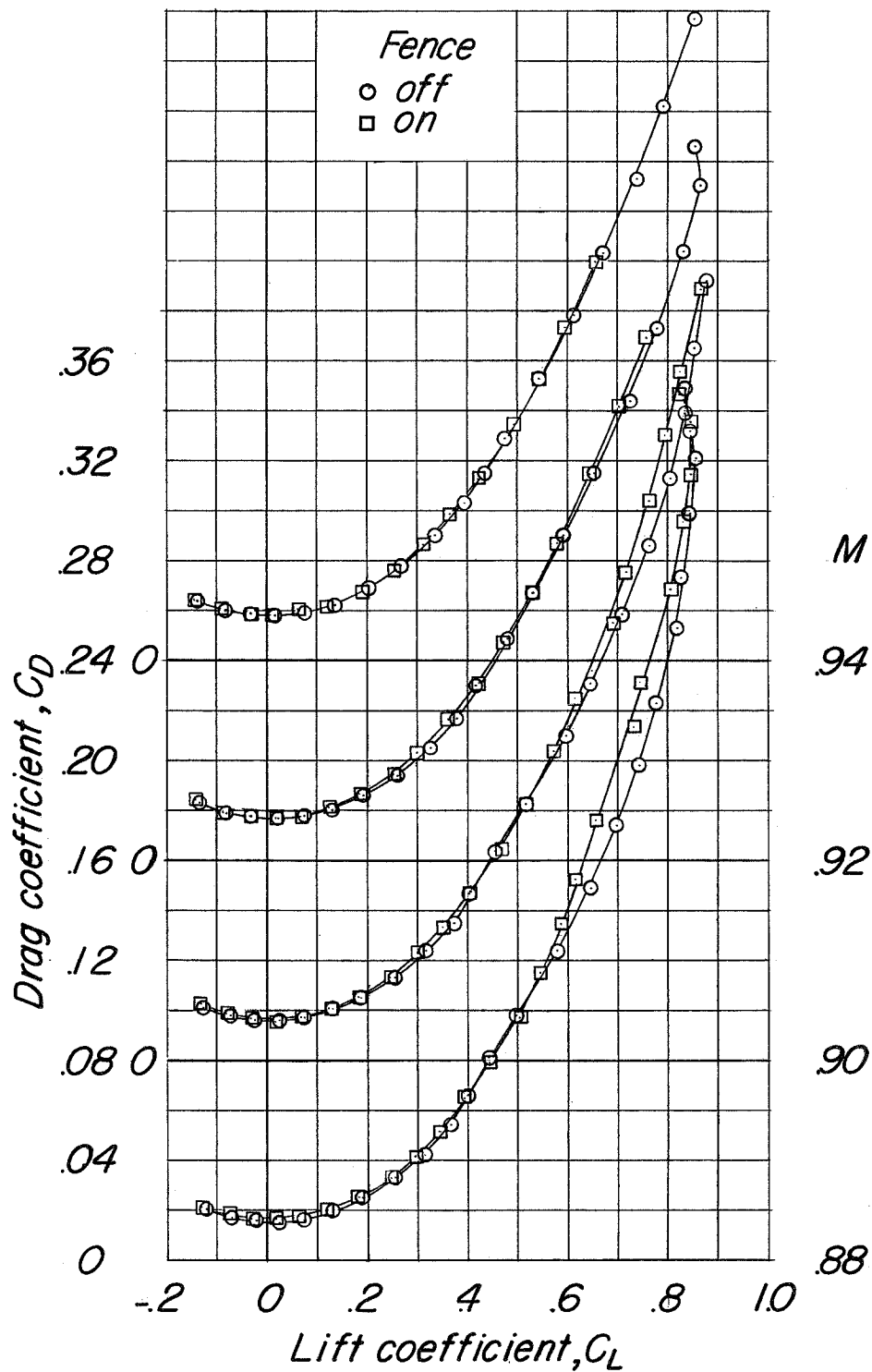
(c)  $C_D$  against  $C_L$ .

Figure 8.- Continued.



(c) Concluded.

Figure 8.- Continued.

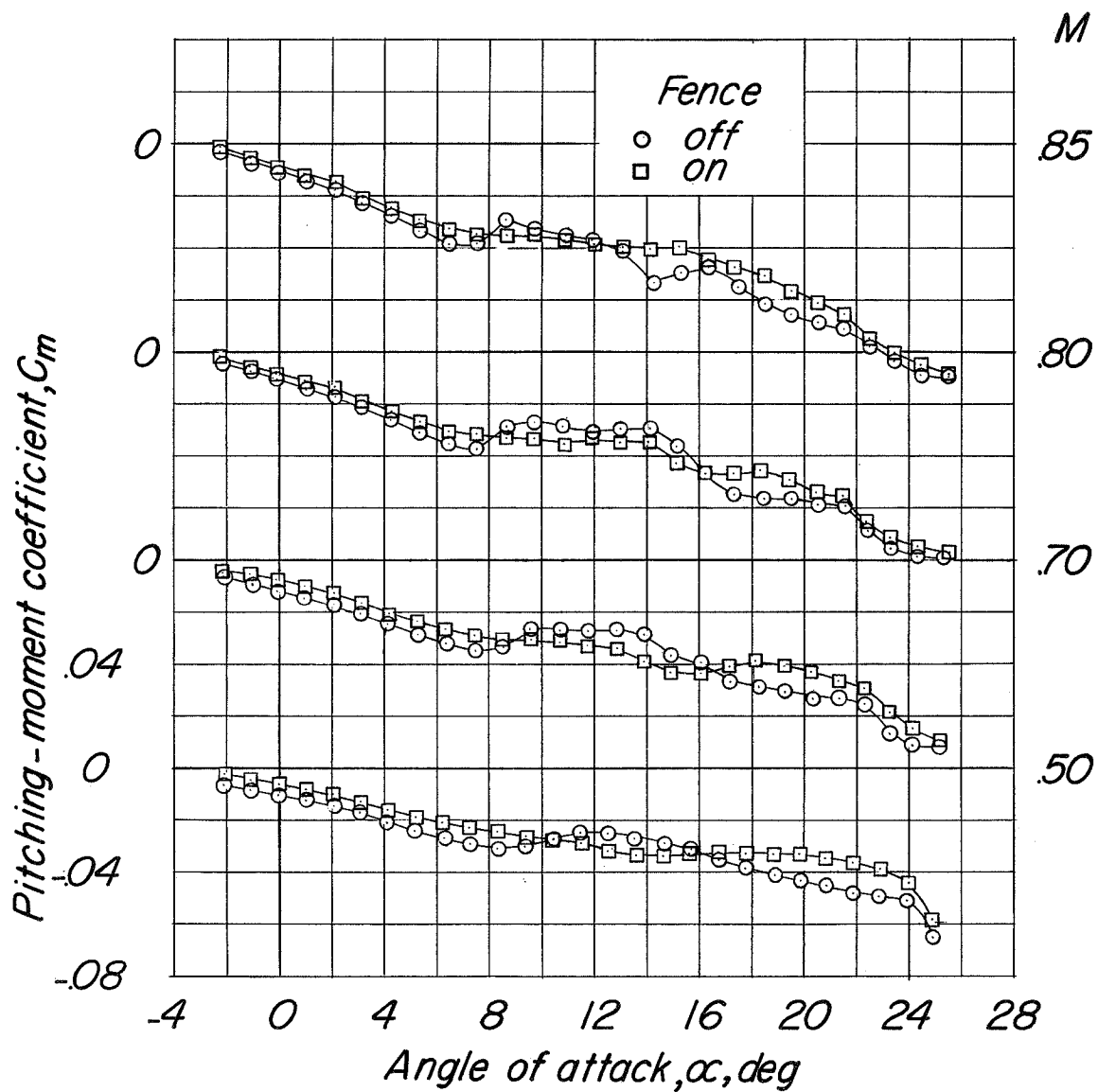
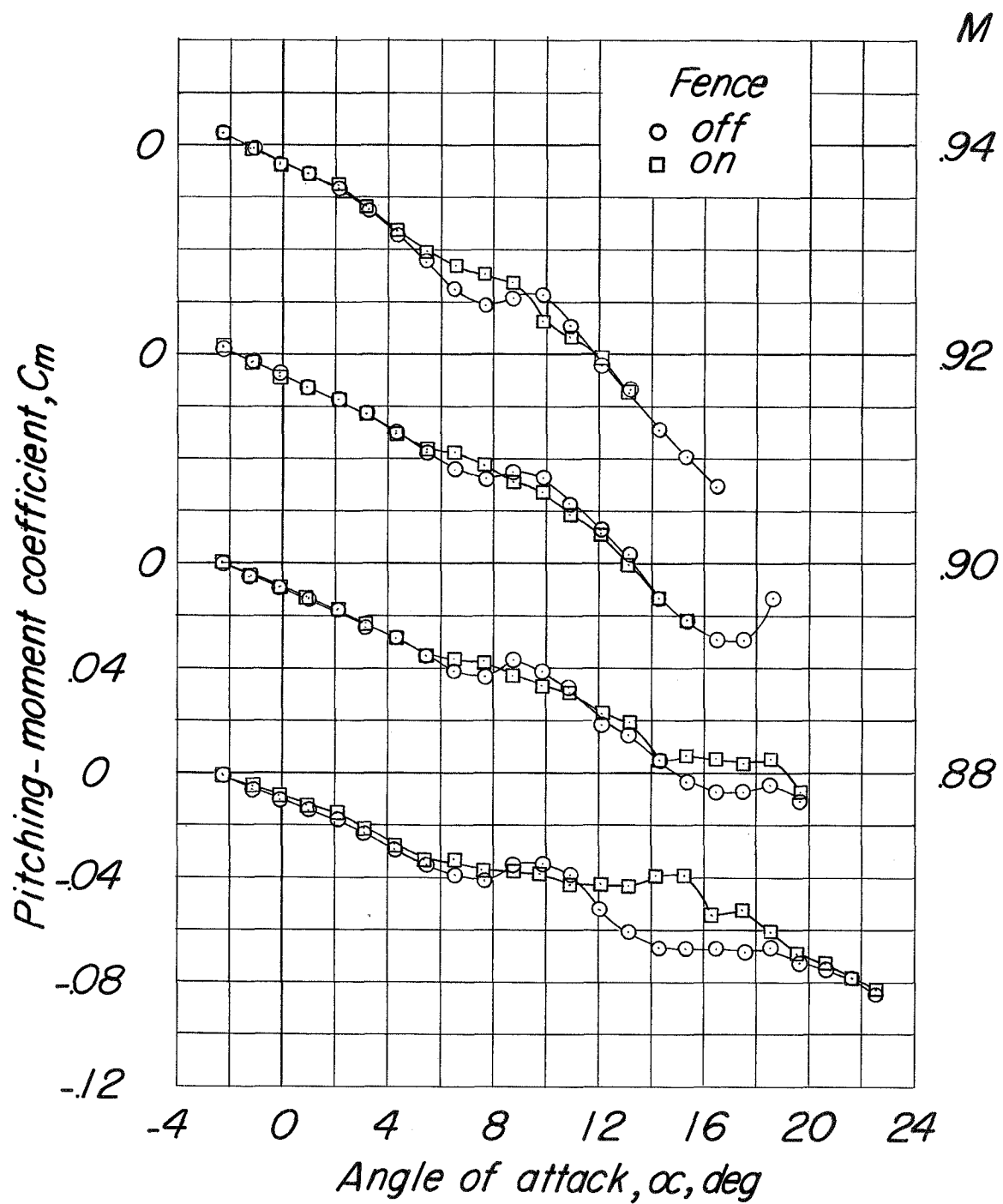
(d)  $C_m$  against  $\alpha$ .

Figure 8.- Continued.



(d) Concluded.

Figure 8.- Continued.

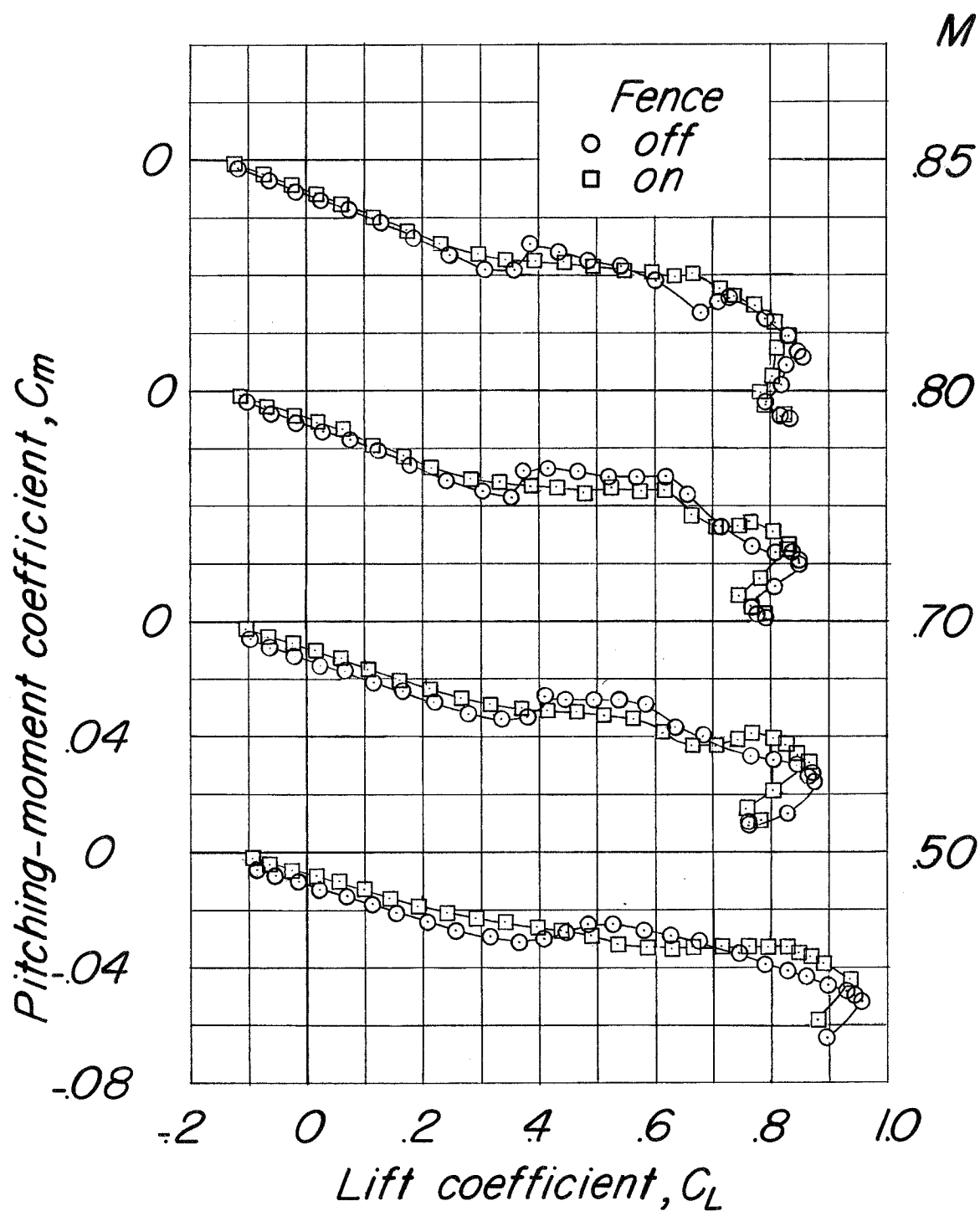
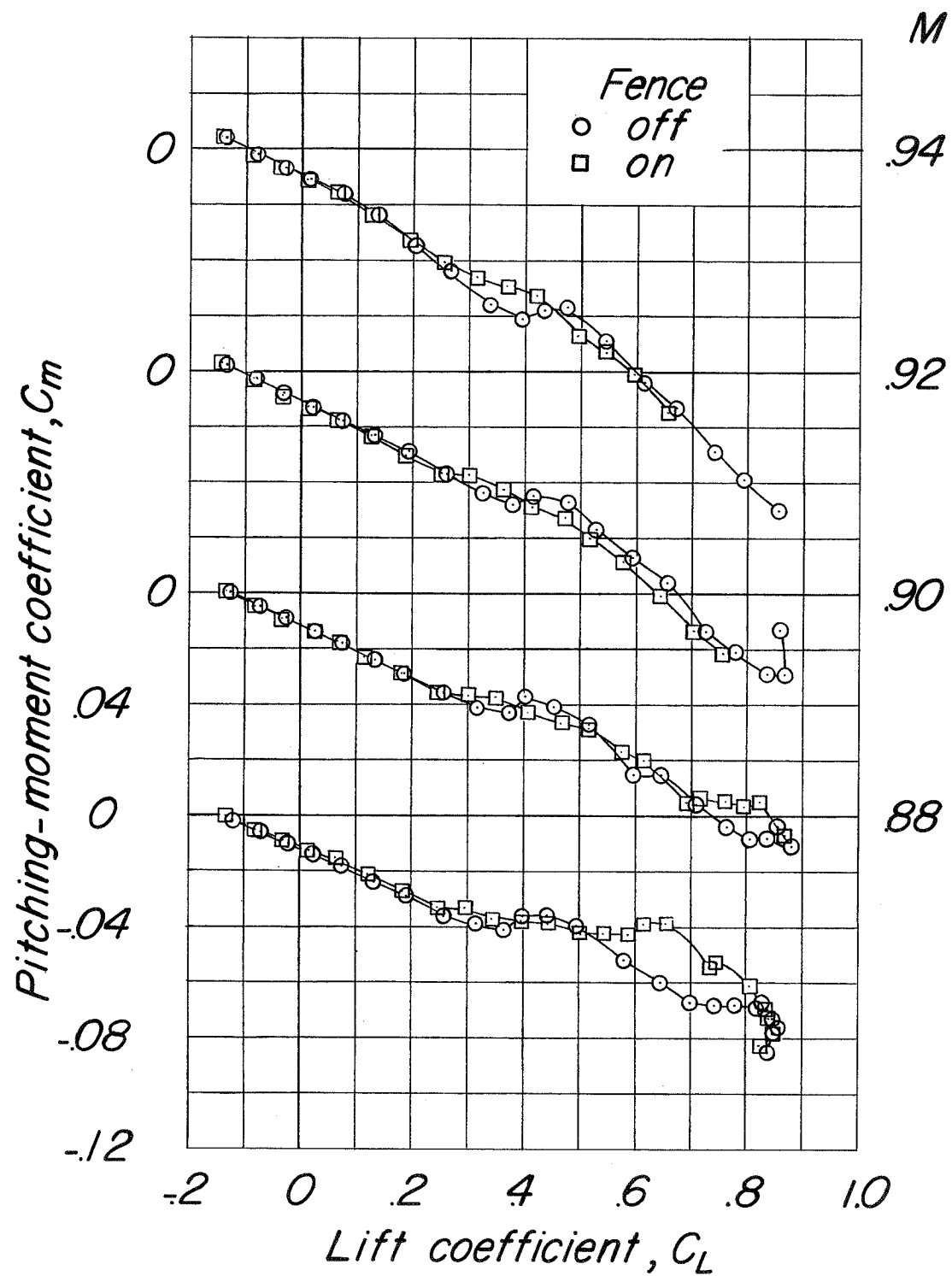
(e)  $C_m$  against  $C_L$ .

Figure 8.- Continued.



(e) Concluded.

Figure 8.- Concluded.

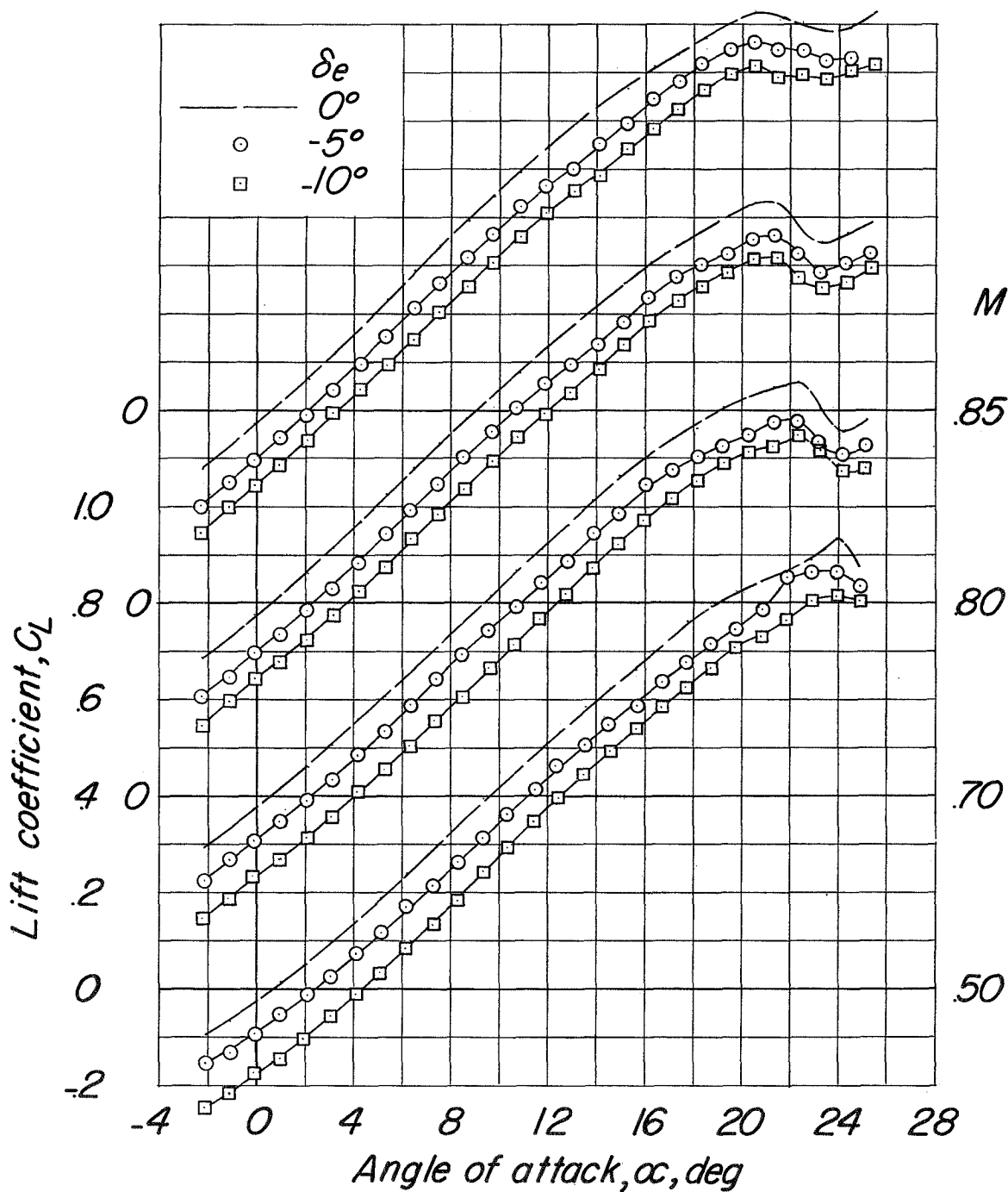
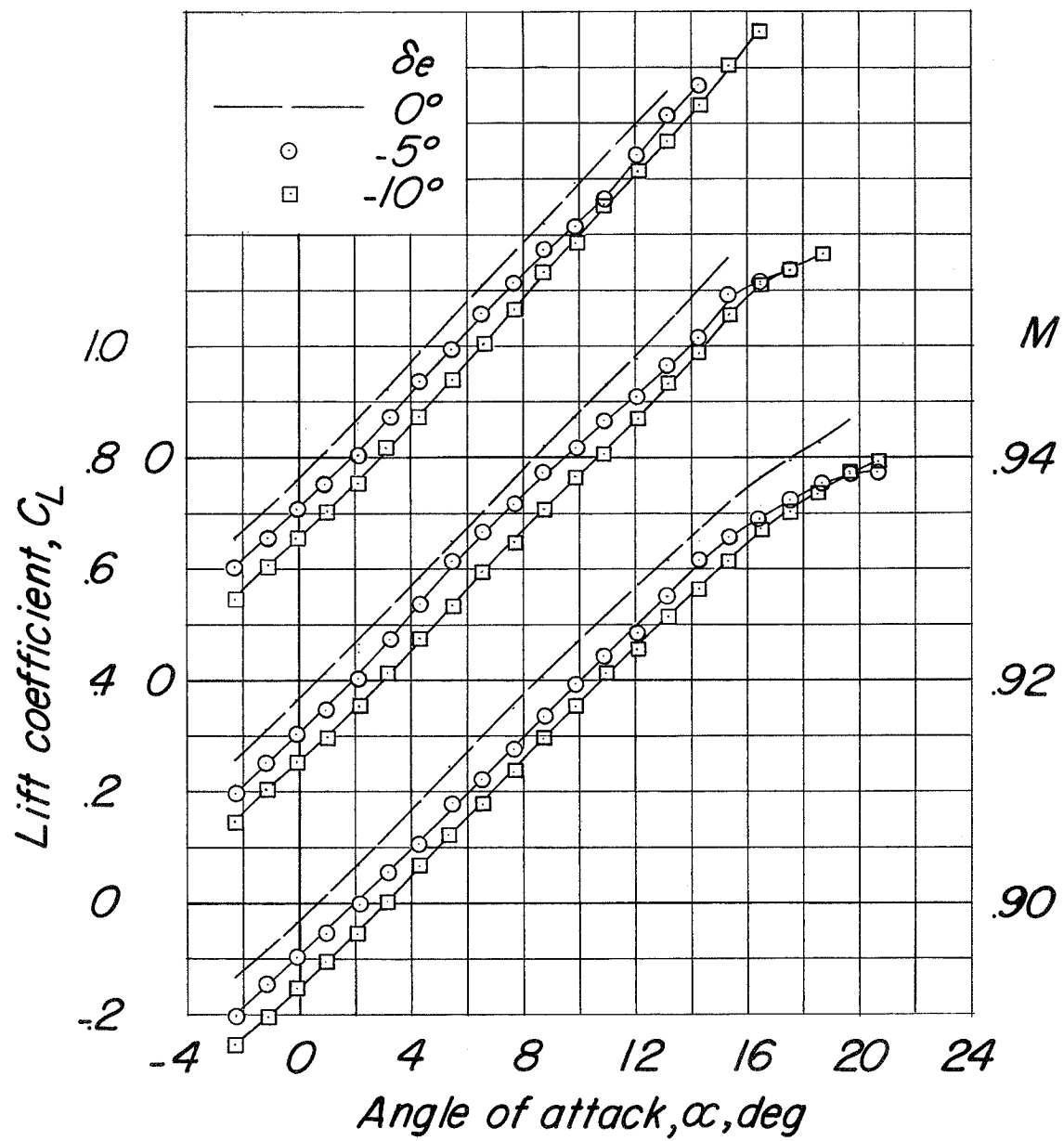
(a)  $C_L$  against  $\alpha$ .

Figure 9.- Basic longitudinal characteristics for configuration  $BCWF_1 V$ ,  
 $\delta_r = 0^\circ$ .



(a) Concluded.

Figure 9.- Continued.

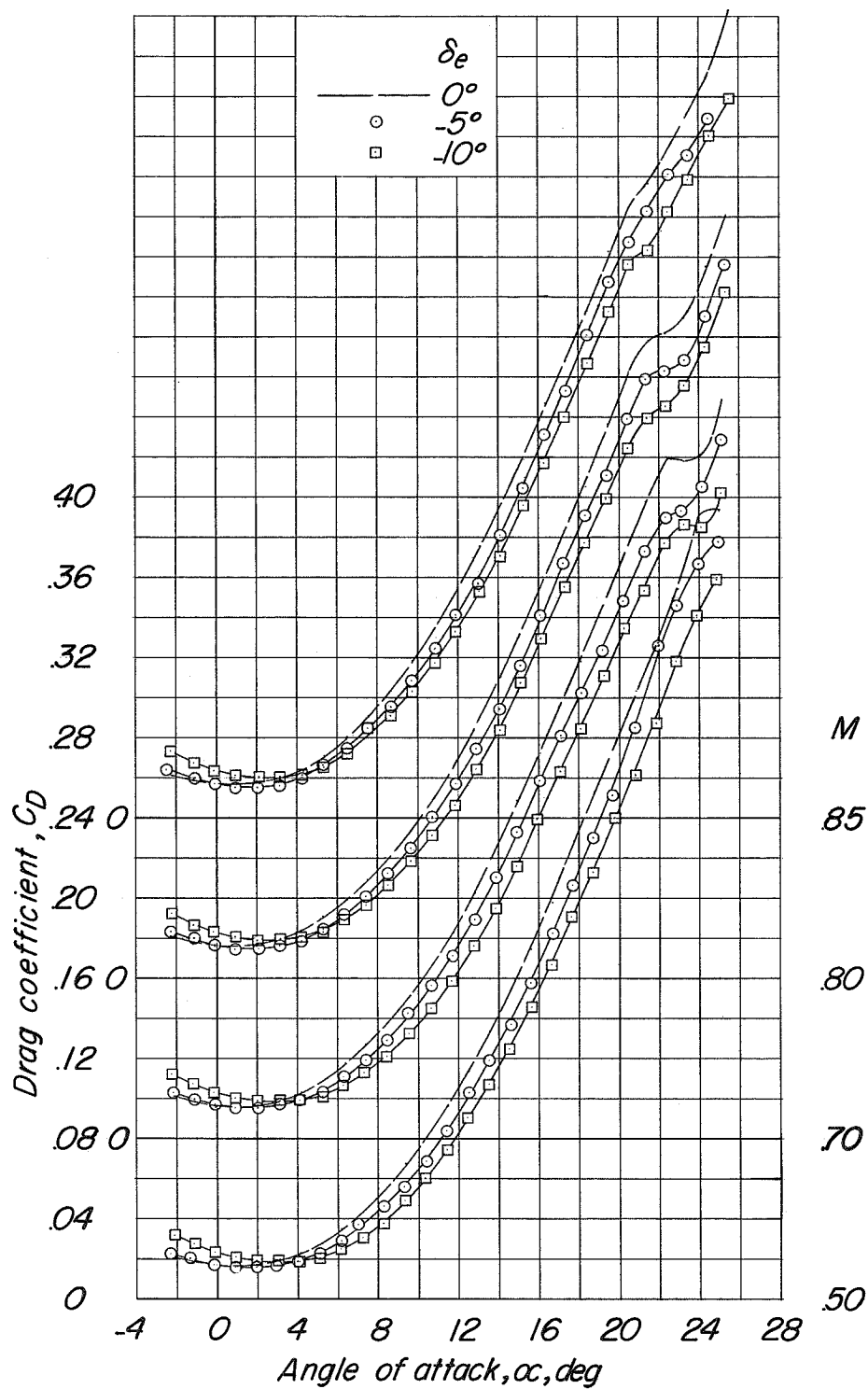
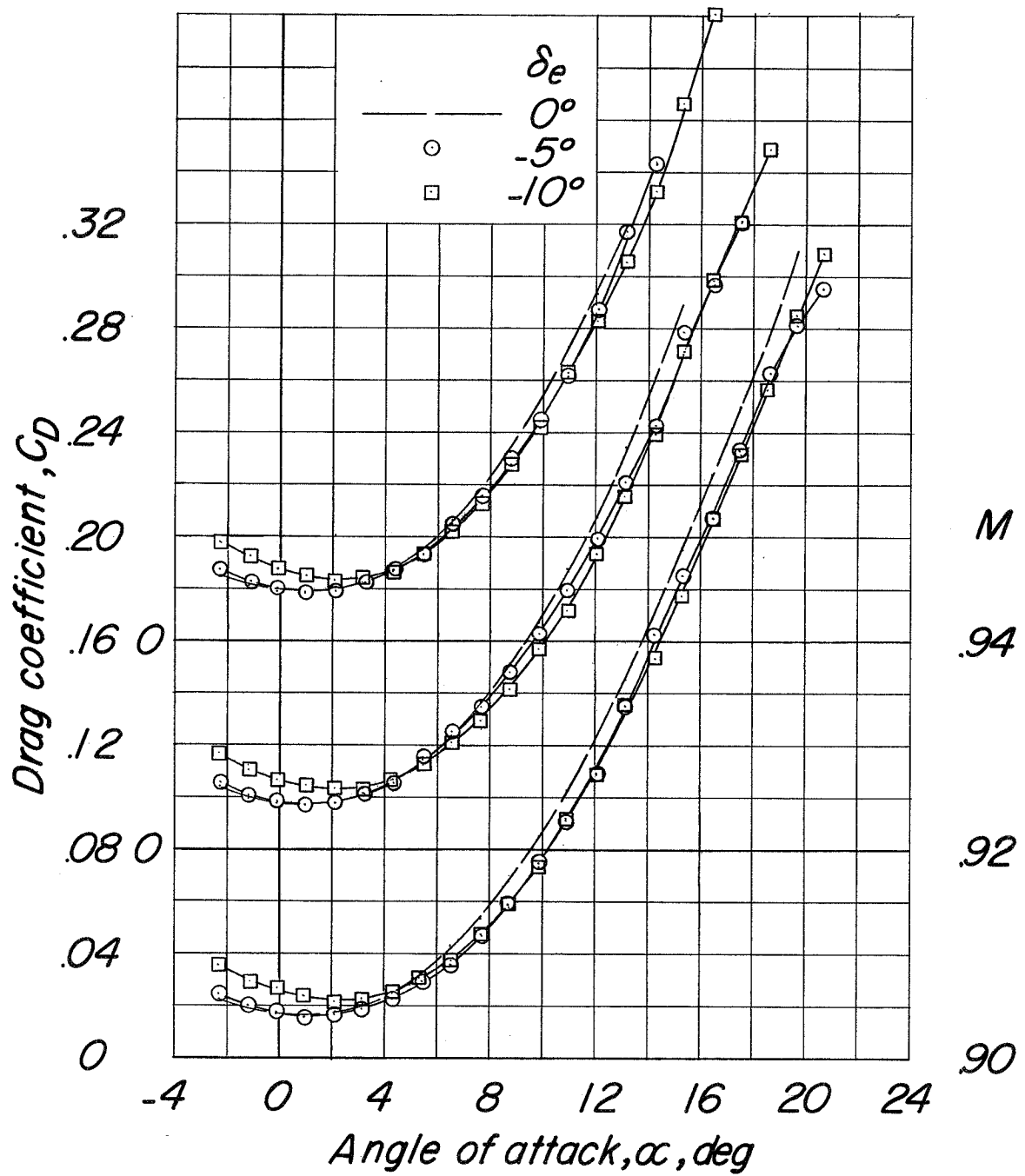
(b)  $C_D$  against  $\alpha$ .

Figure 9.- Continued.



(b) Concluded.

Figure 9.- Continued.

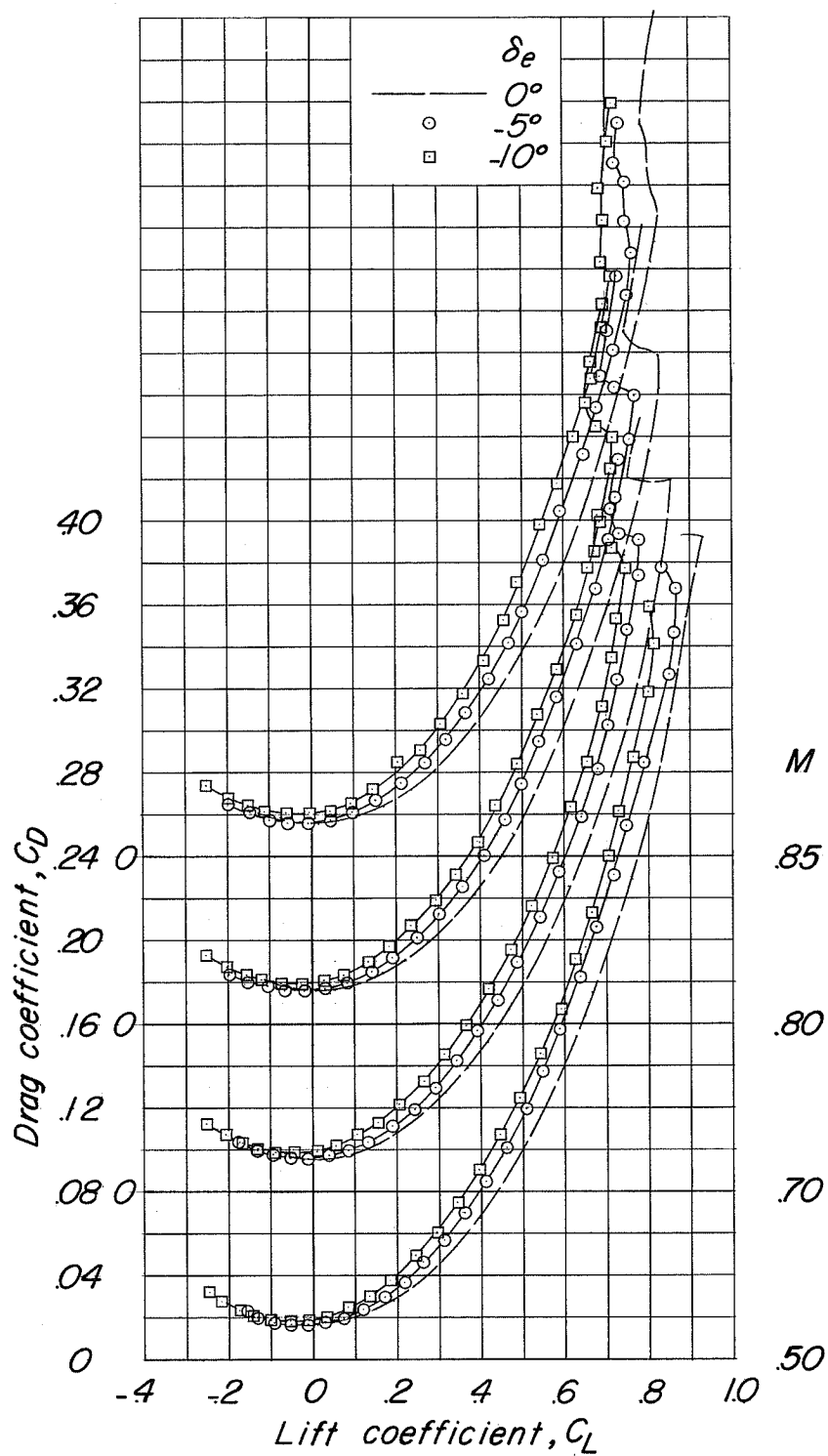
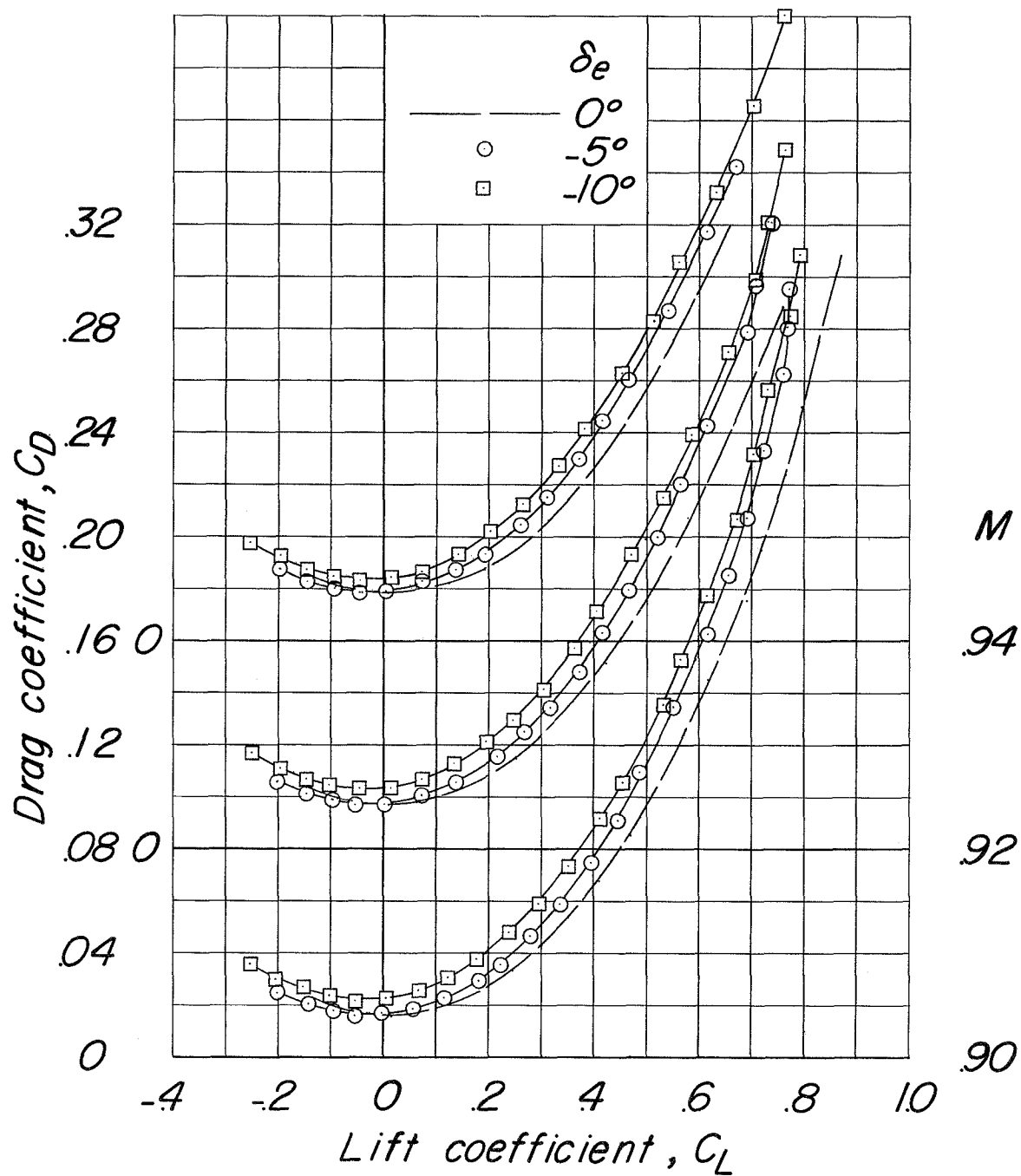
(c)  $C_D$  against  $C_L$ .

Figure 9.- Continued.



(c) Concluded.

Figure 9.- Continued.

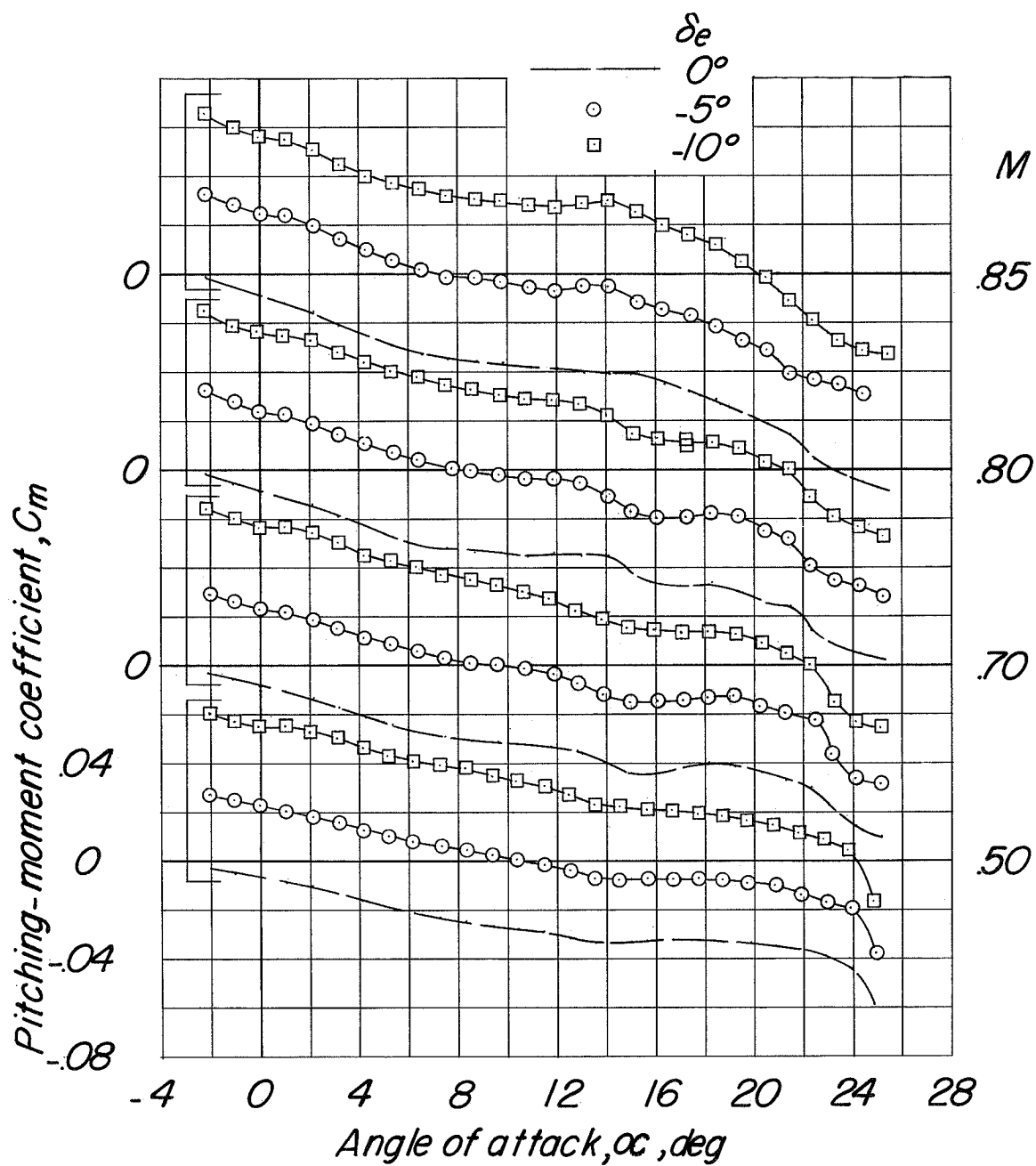
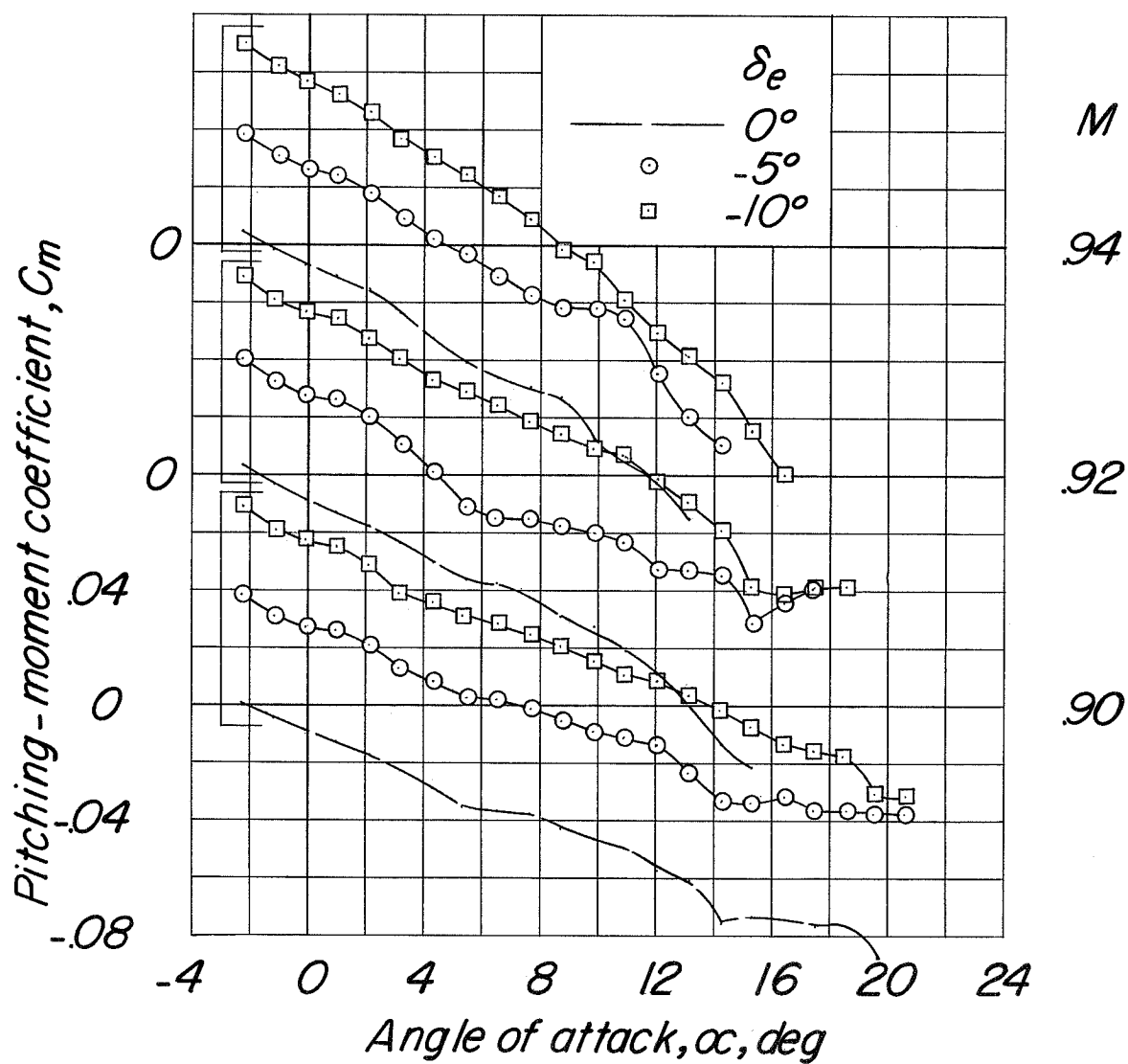
(d)  $C_m$  against  $\alpha$ .

Figure 9.- Continued.



(d) Concluded.

Figure 9.- Continued.

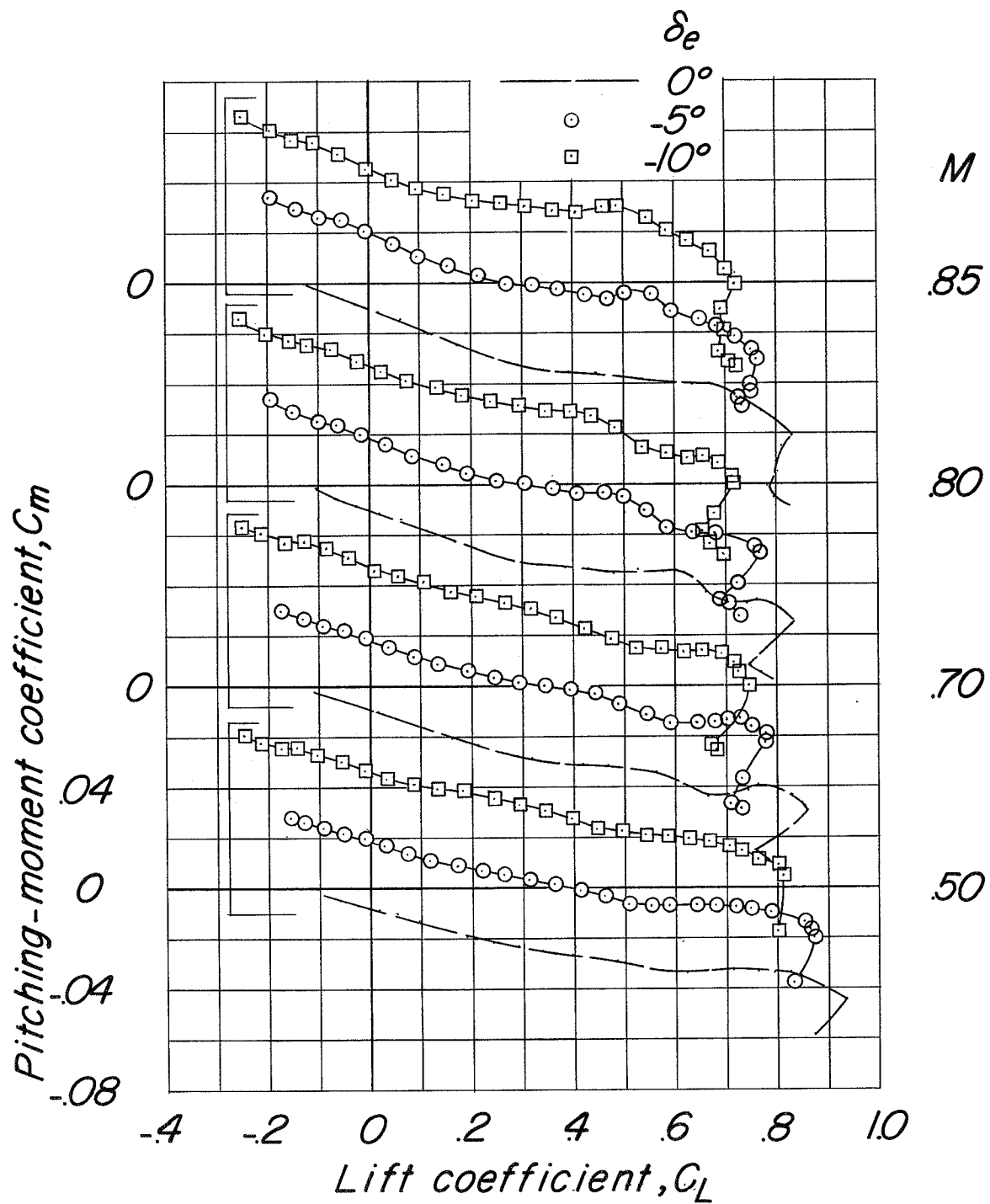
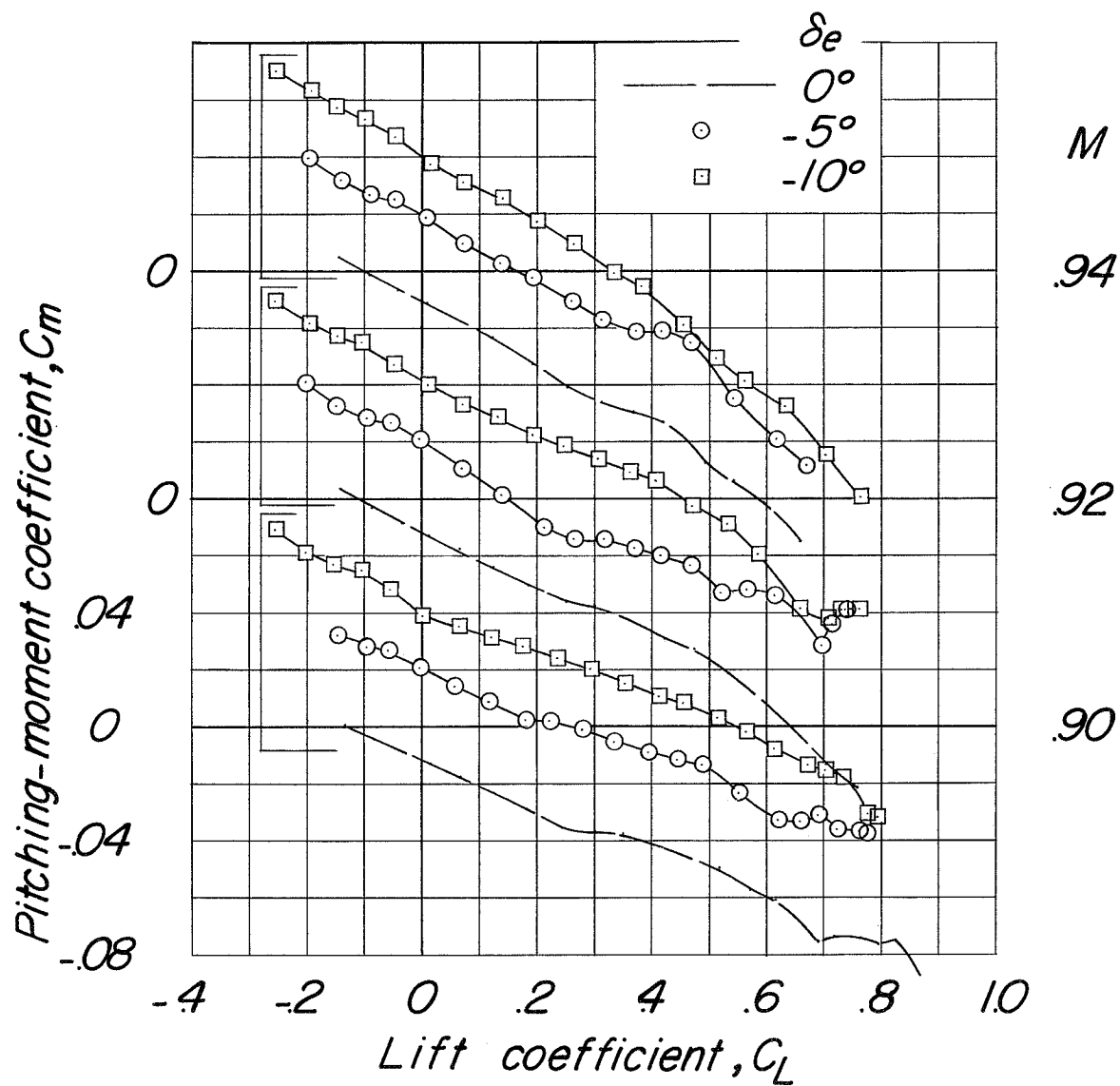
(e)  $C_m$  against  $C_L$ .

Figure 9.- Continued.



(e) Concluded.

Figure 9.- Concluded.

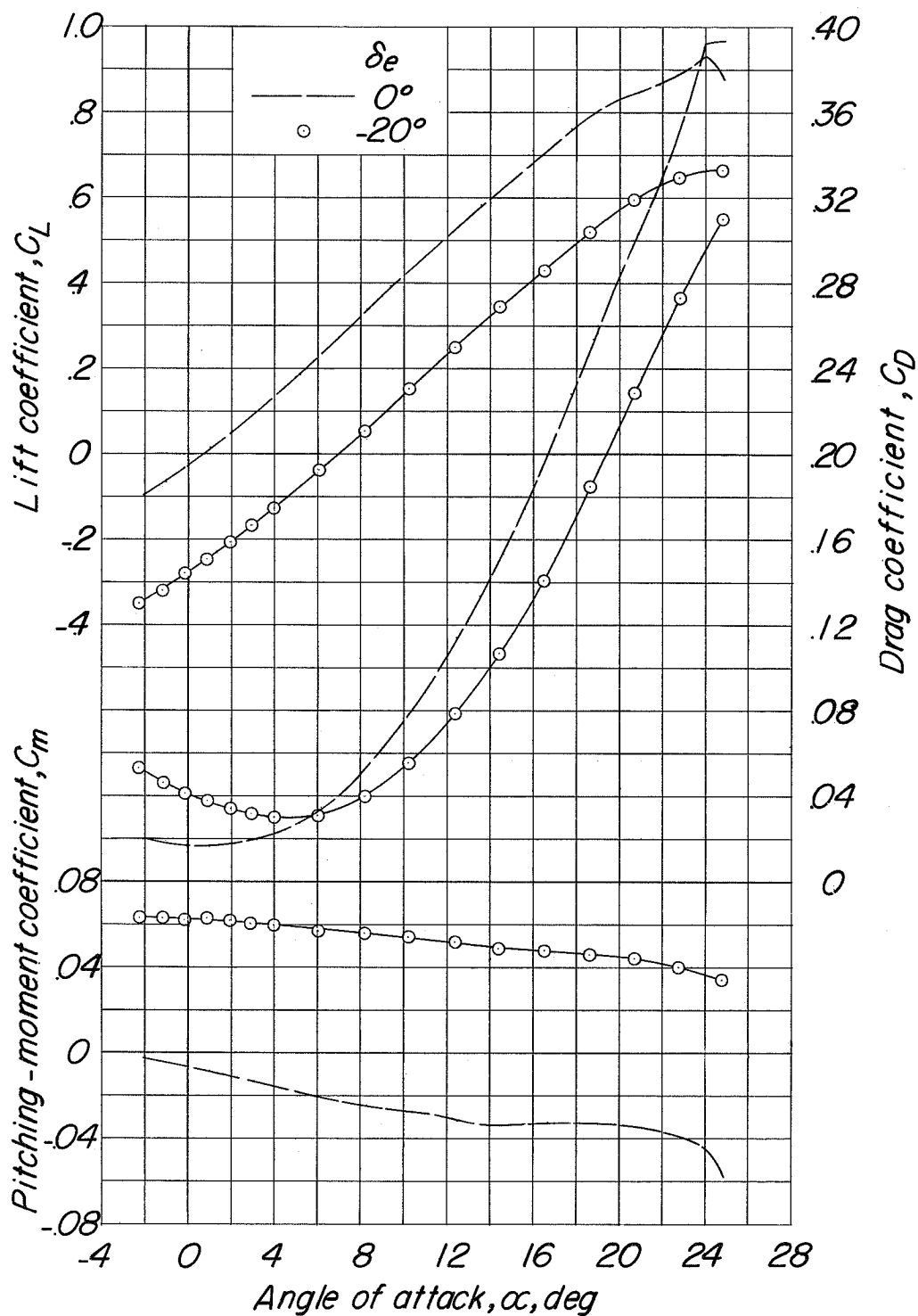


Figure 10.- Basic longitudinal characteristics for configuration BCWF<sub>1</sub>V,  
 $\delta_r = 0^\circ$ , at a Mach number of 0.50.

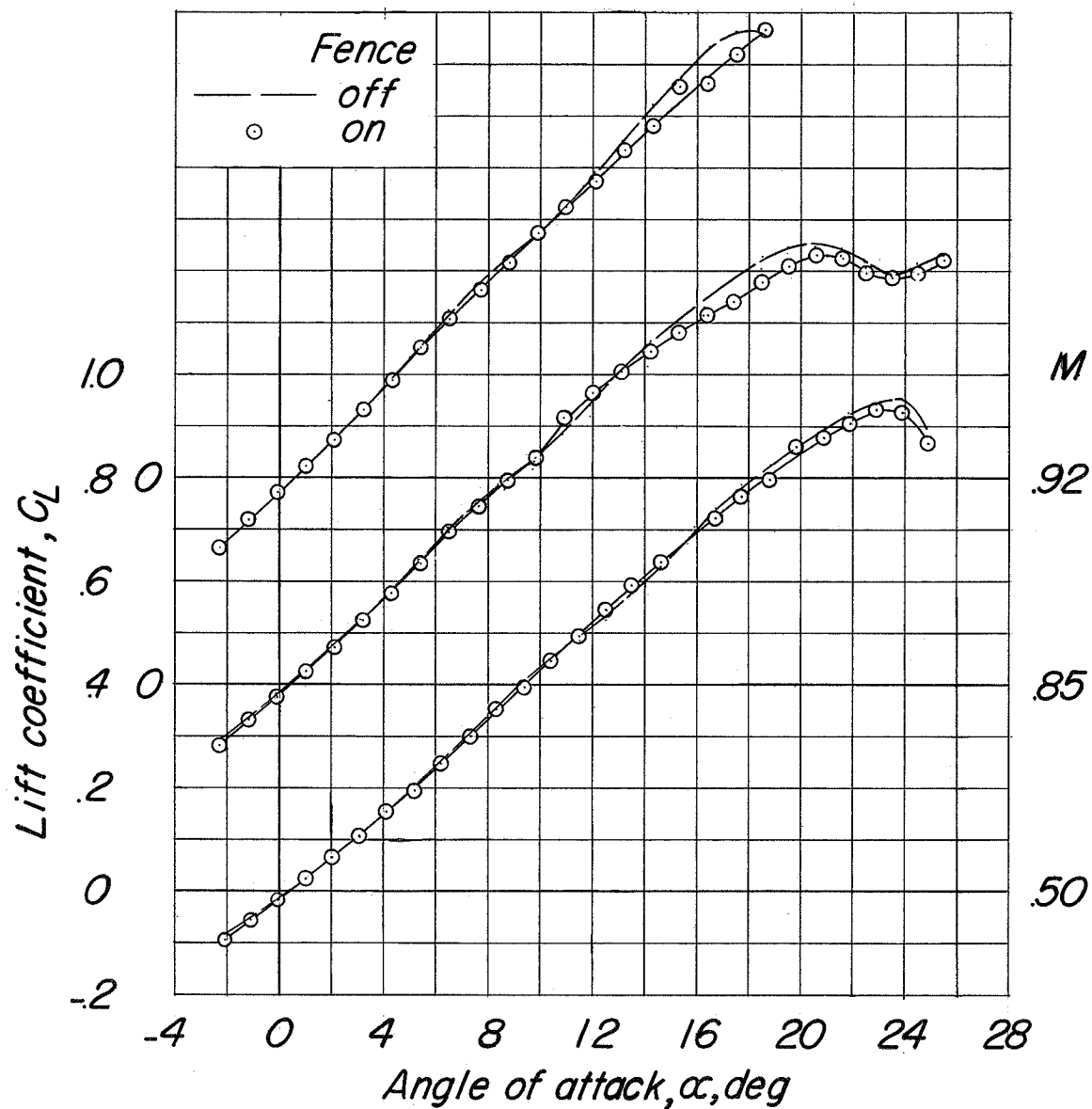
(a)  $C_L$  against  $\alpha$ .

Figure 11.- Basic longitudinal characteristics for configuration BCWV,  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ , with and without fence 2.

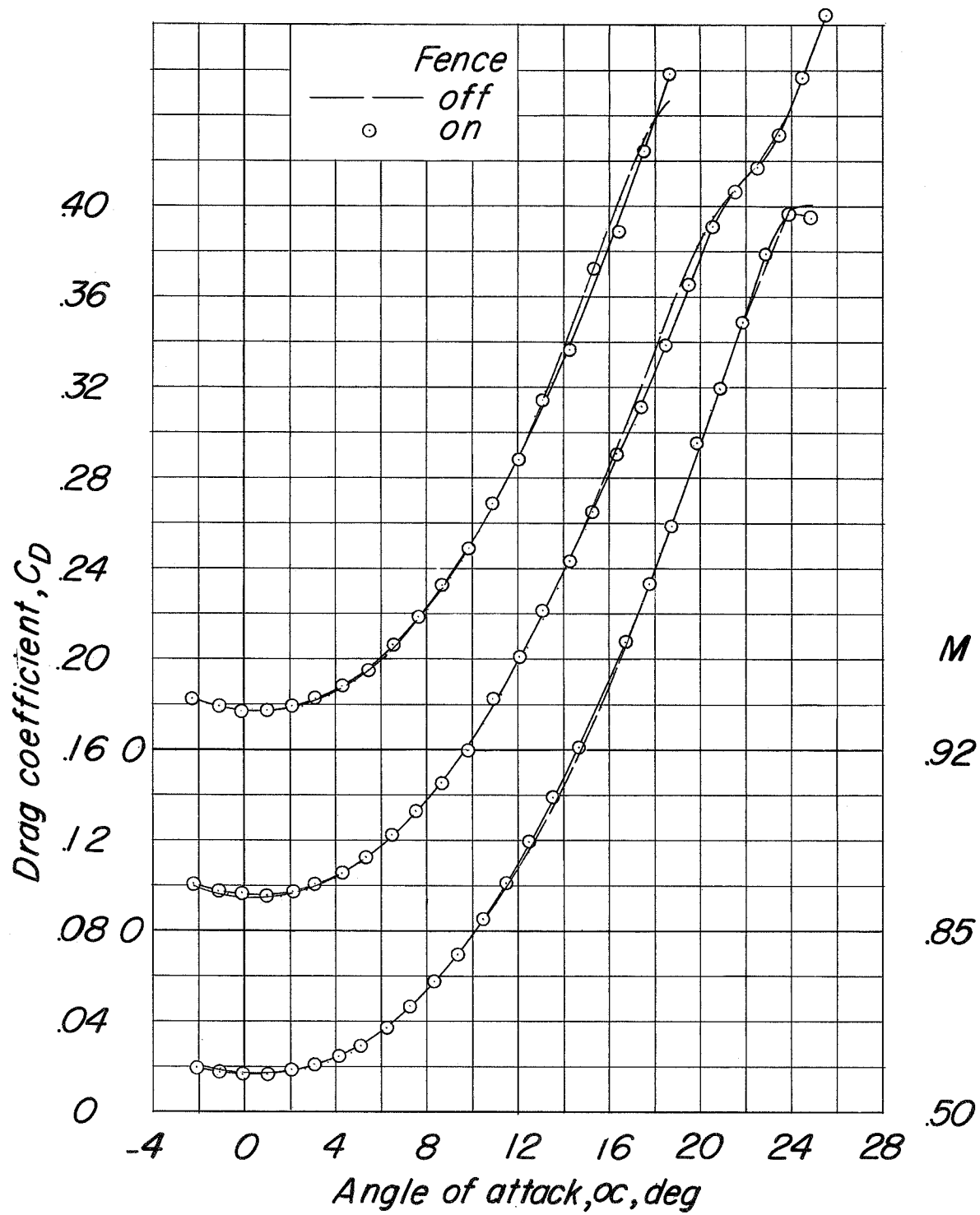
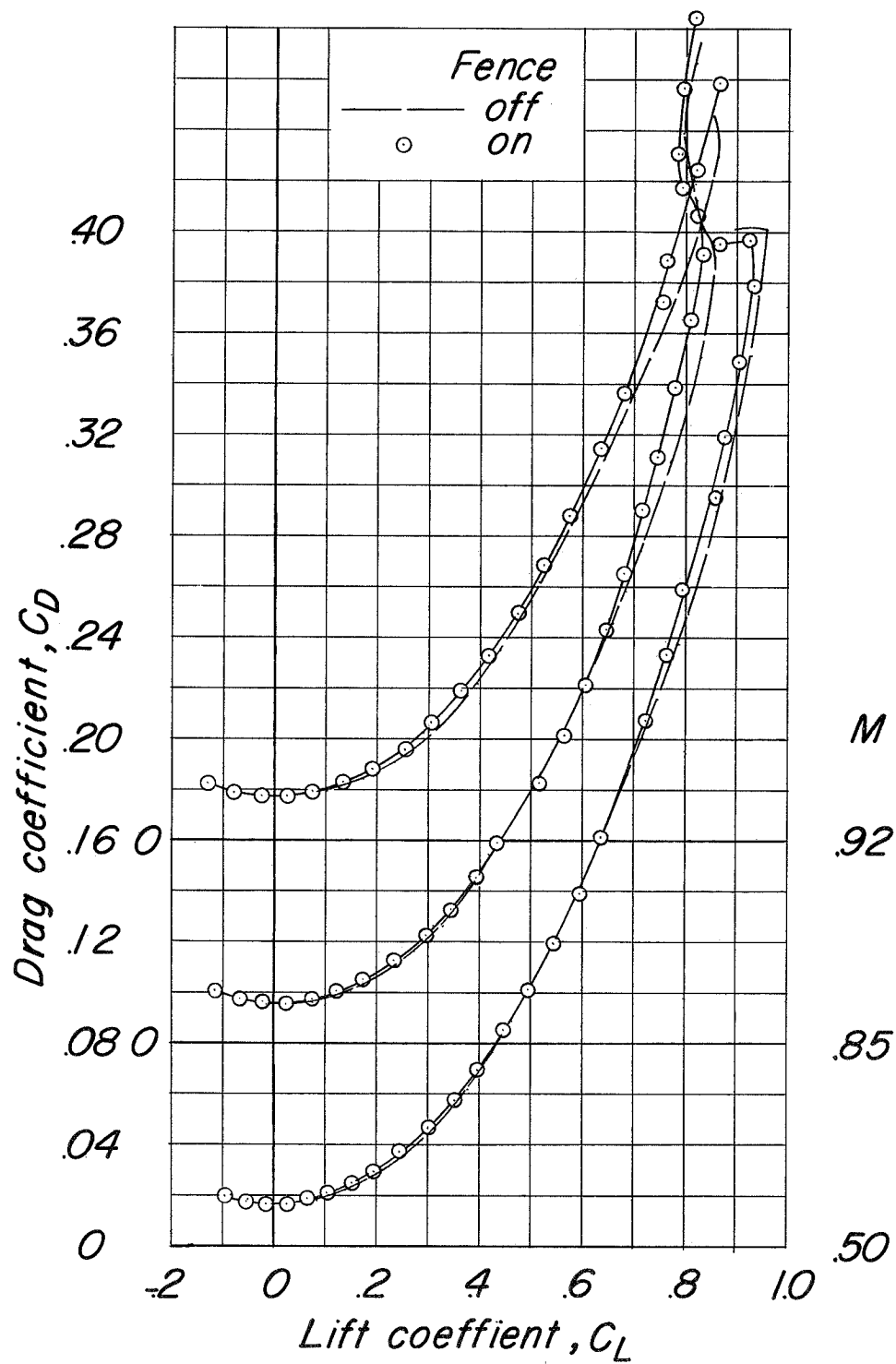
(b)  $C_D$  against  $\alpha$ .

Figure 11.- Continued.



(c)  $C_D$  against  $C_L$ .

Figure 11.- Continued.

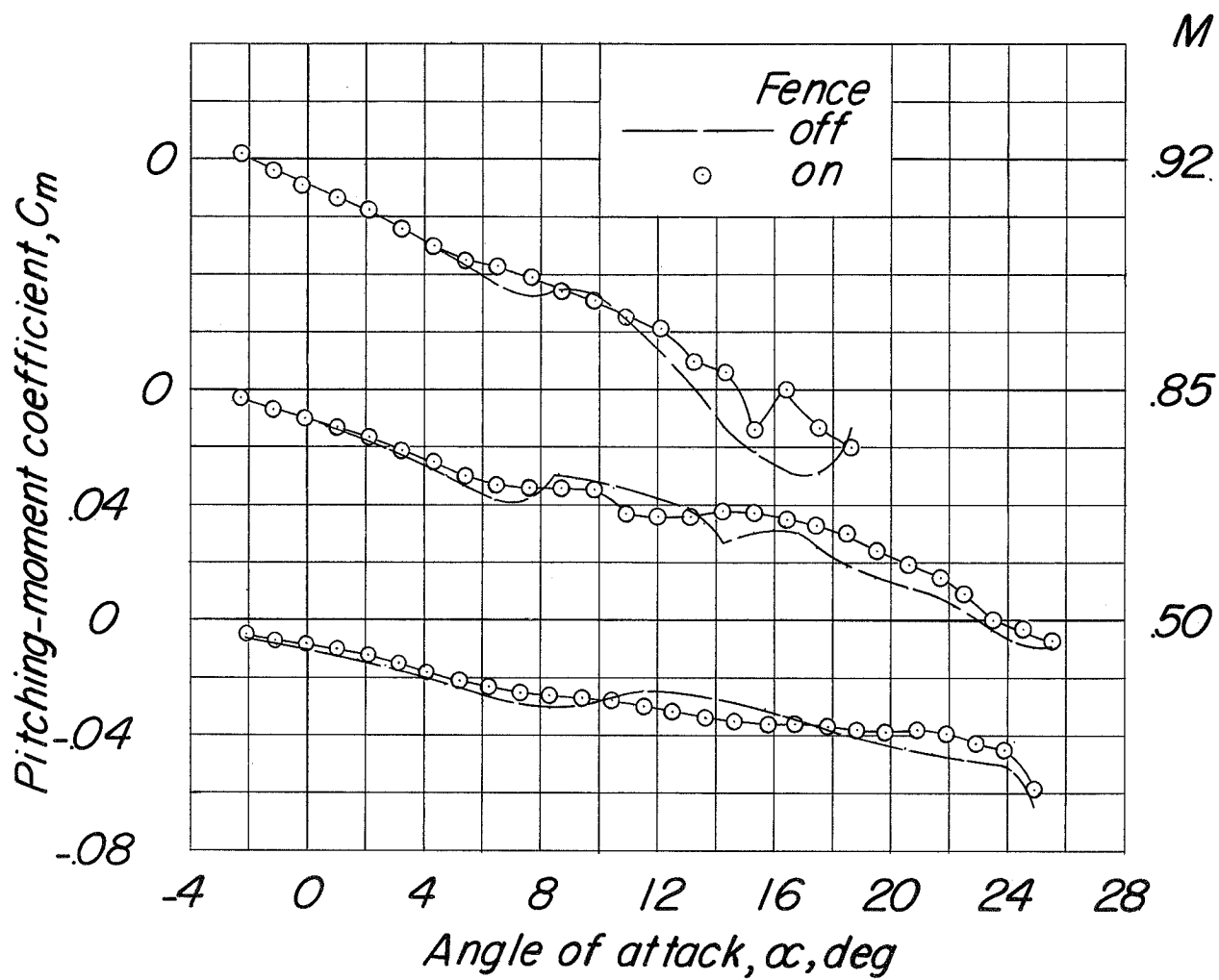
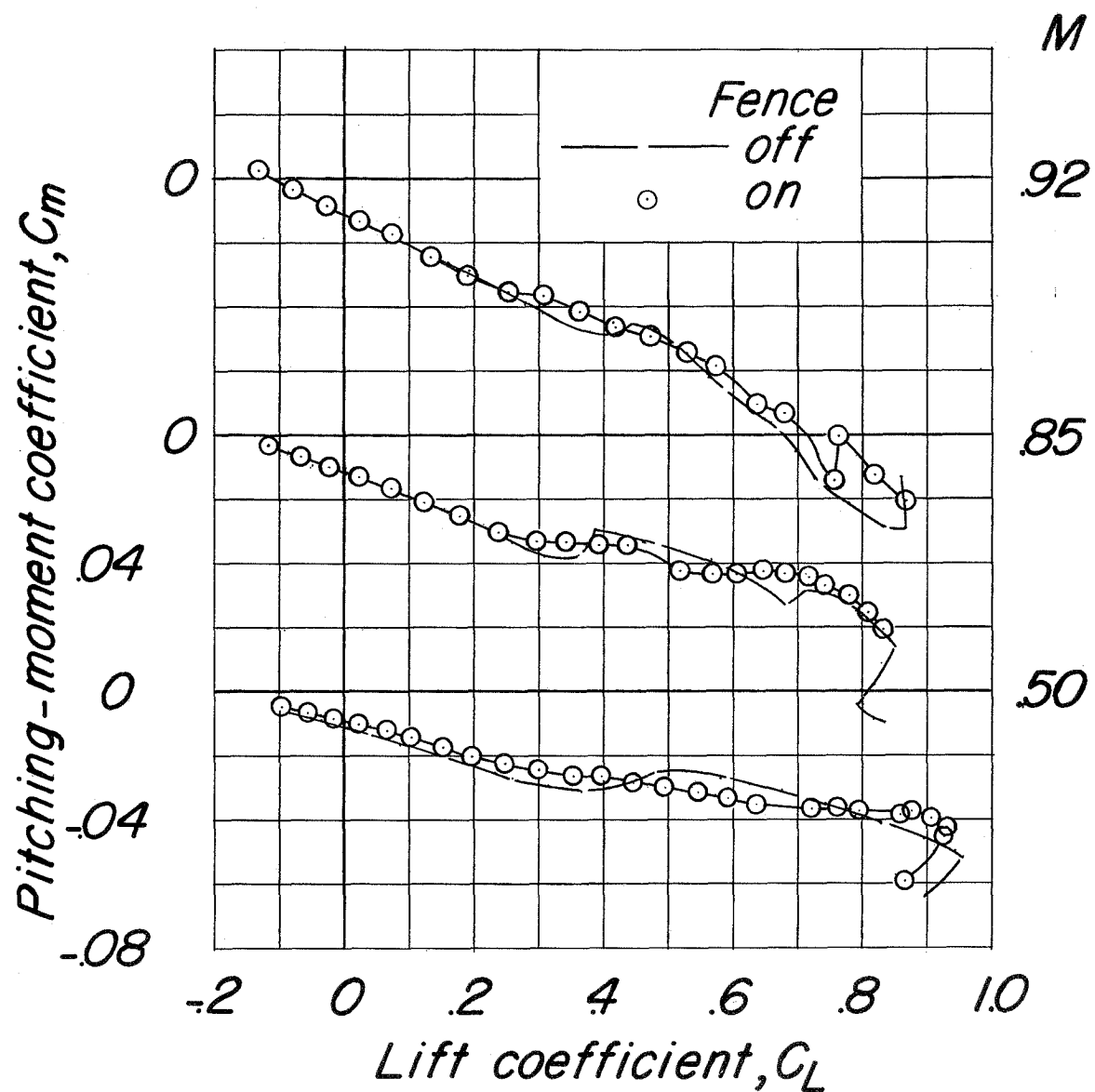
(d)  $C_m$  against  $\alpha$ .

Figure 11.- Continued.



(e)  $C_m$  against  $C_L$ .

Figure 11.- Concluded.

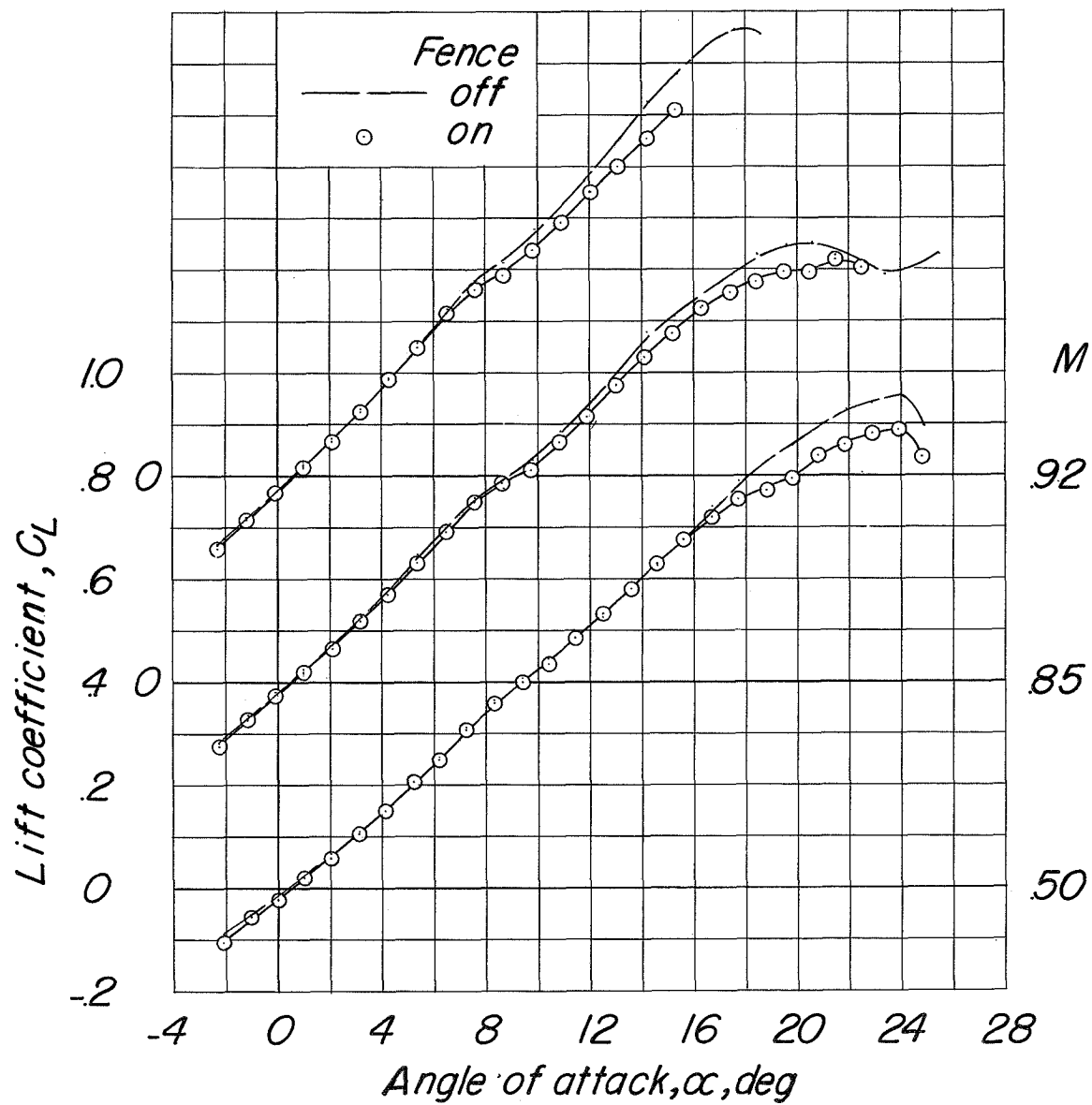
(a)  $C_L$  against  $\alpha$ .

Figure 12.- Basic longitudinal characteristics for configuration BCWV,  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ , with and without fence 3.

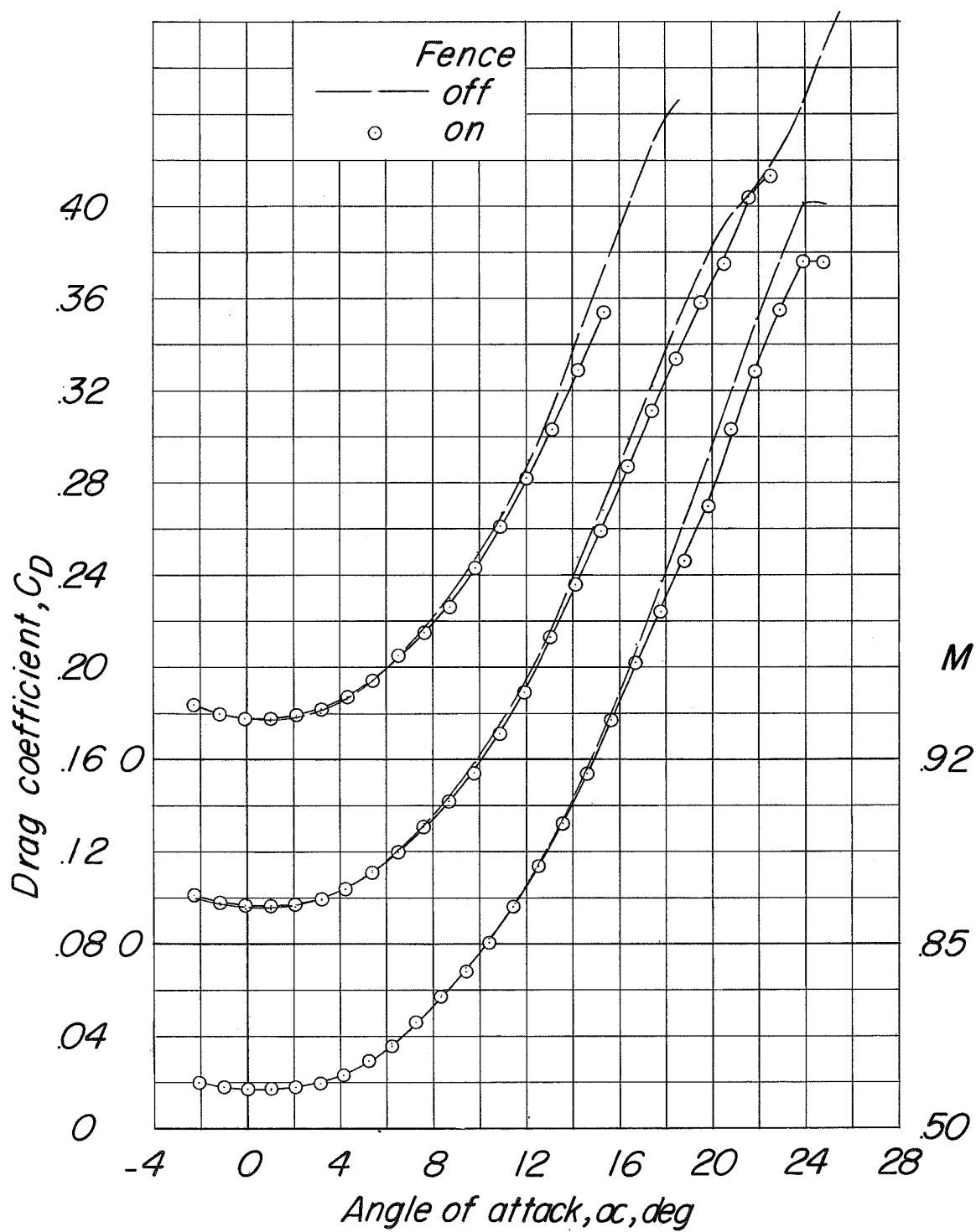
(b)  $C_D$  against  $\alpha$ .

Figure 12.- Continued.

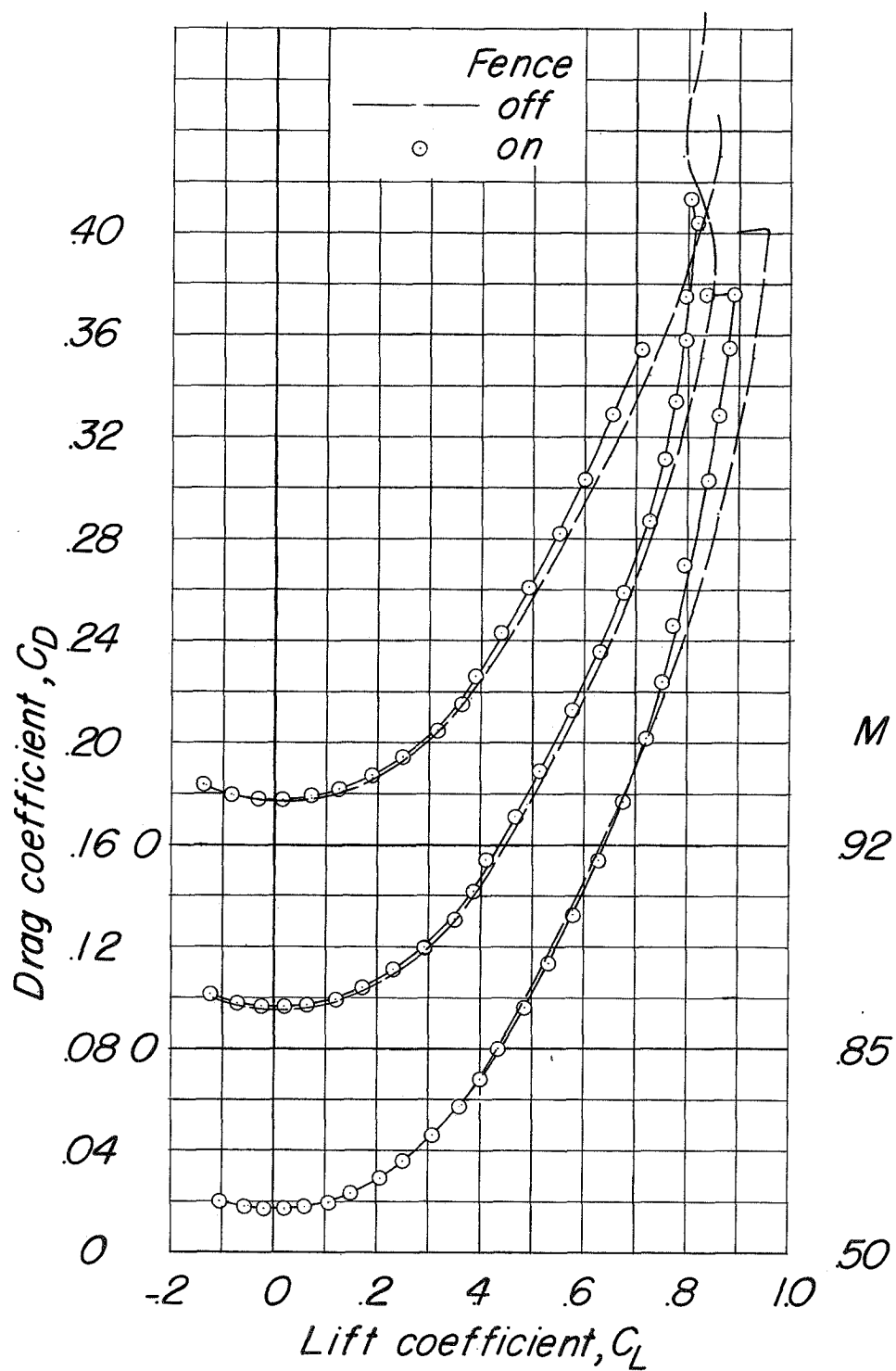
(c)  $C_D$  against  $C_L$ .

Figure 12.- Continued.

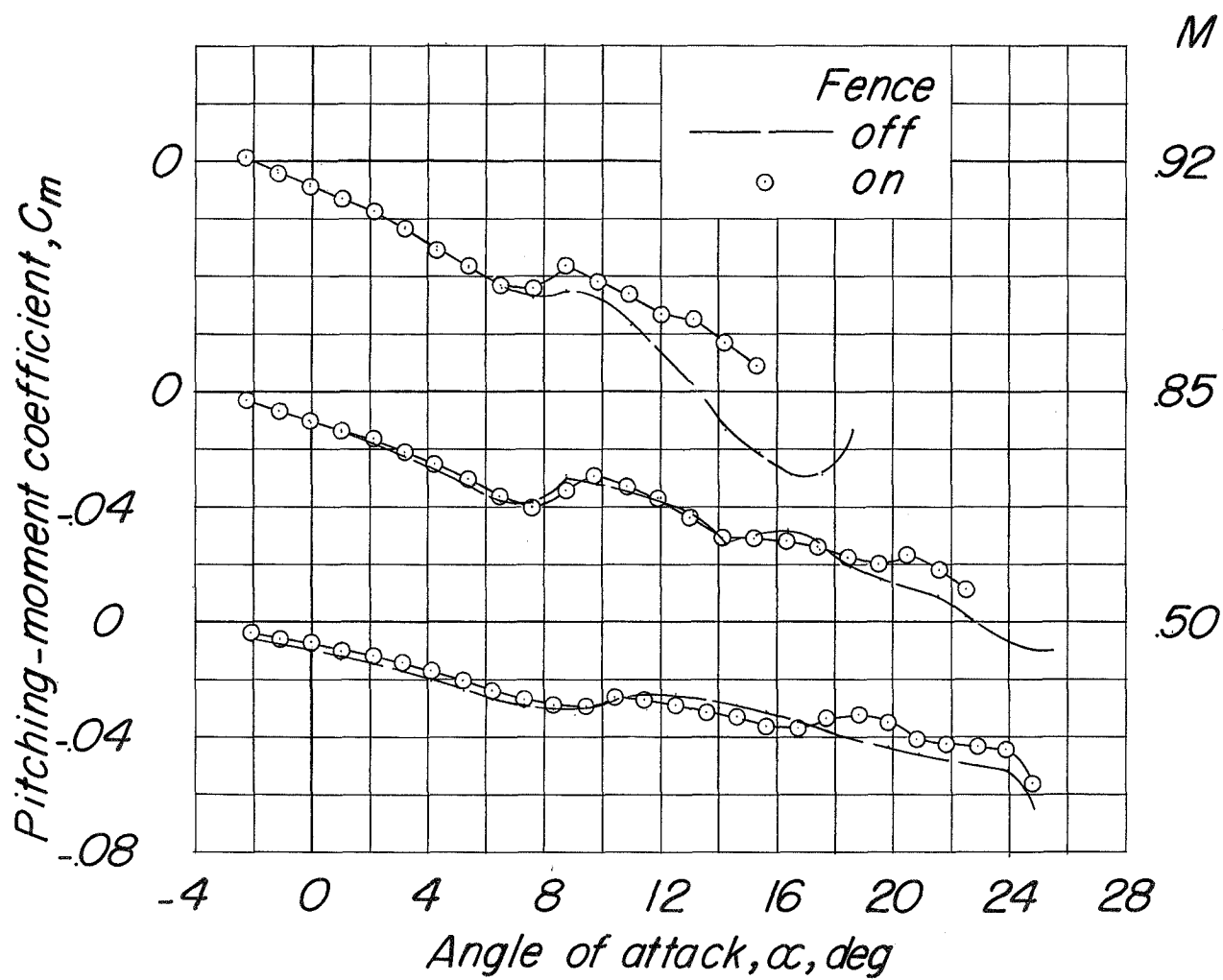
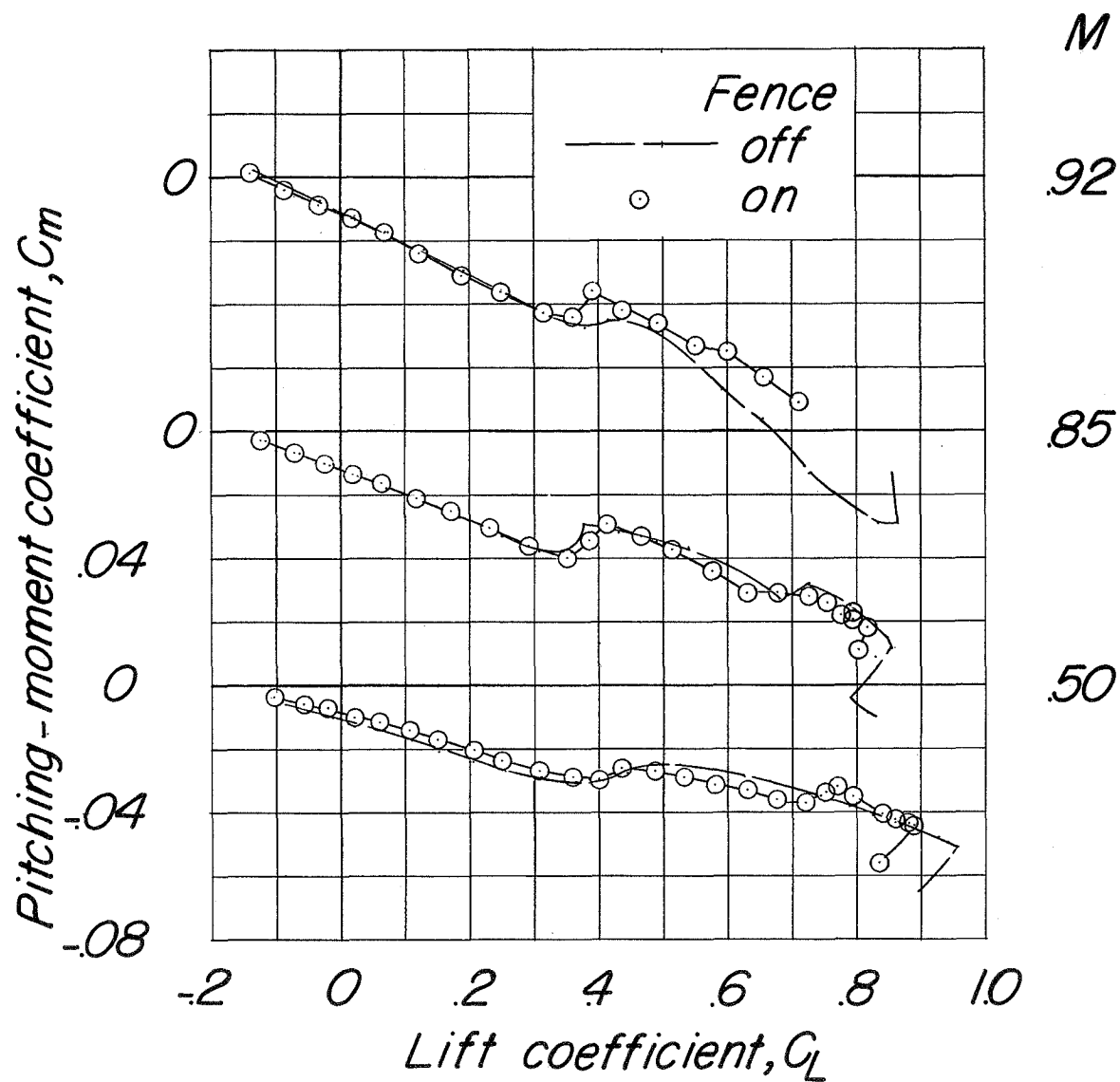
(d)  $C_m$  against  $\alpha$ .

Figure 12.- Continued.



(e)  $C_m$  against  $C_L$ .

Figure 12.- Concluded.

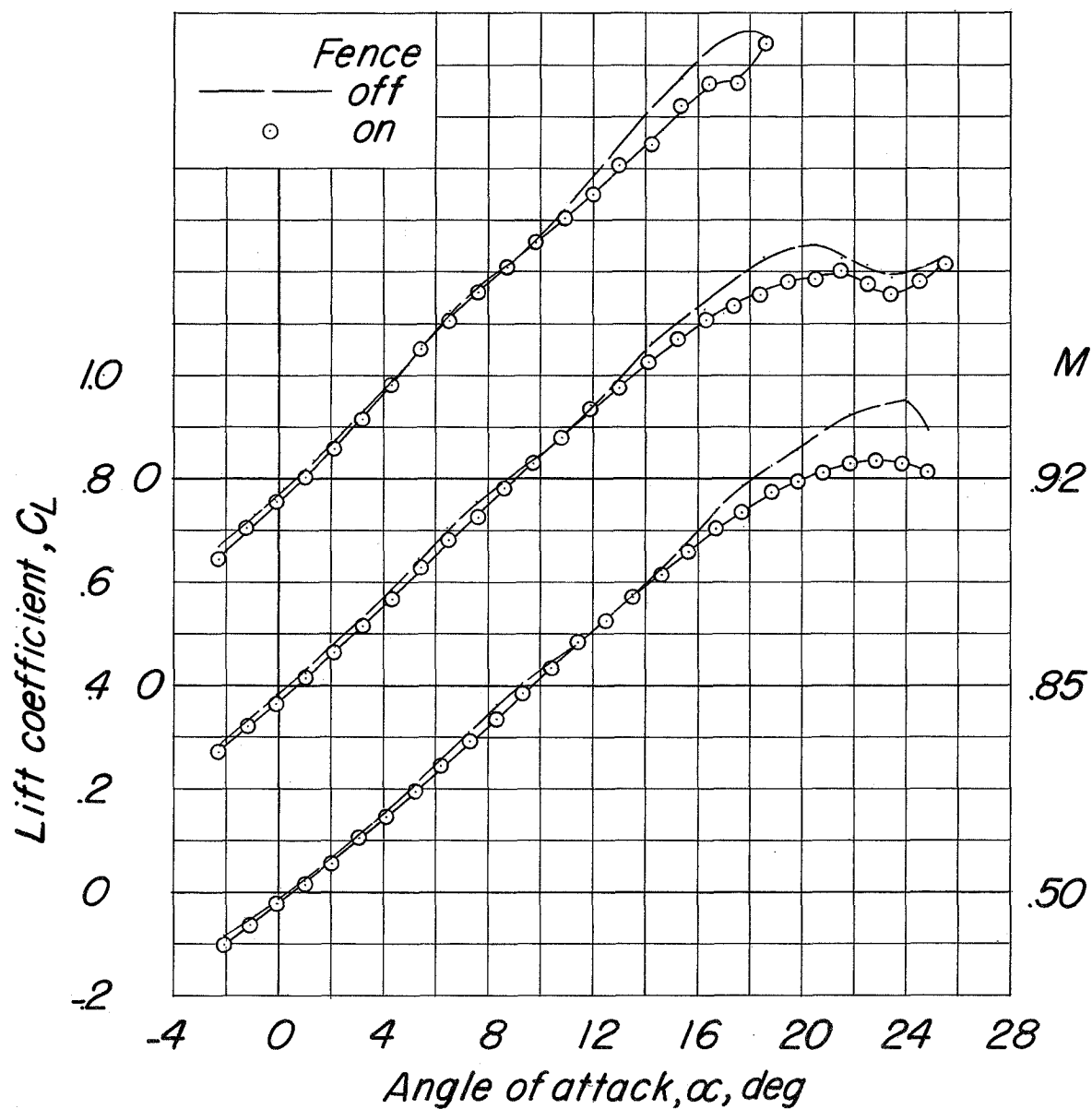
(a)  $C_L$  against  $\alpha$ .

Figure 13.- Basic longitudinal characteristics for configuration BCWV,  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ , with and without fences 2 plus 3.

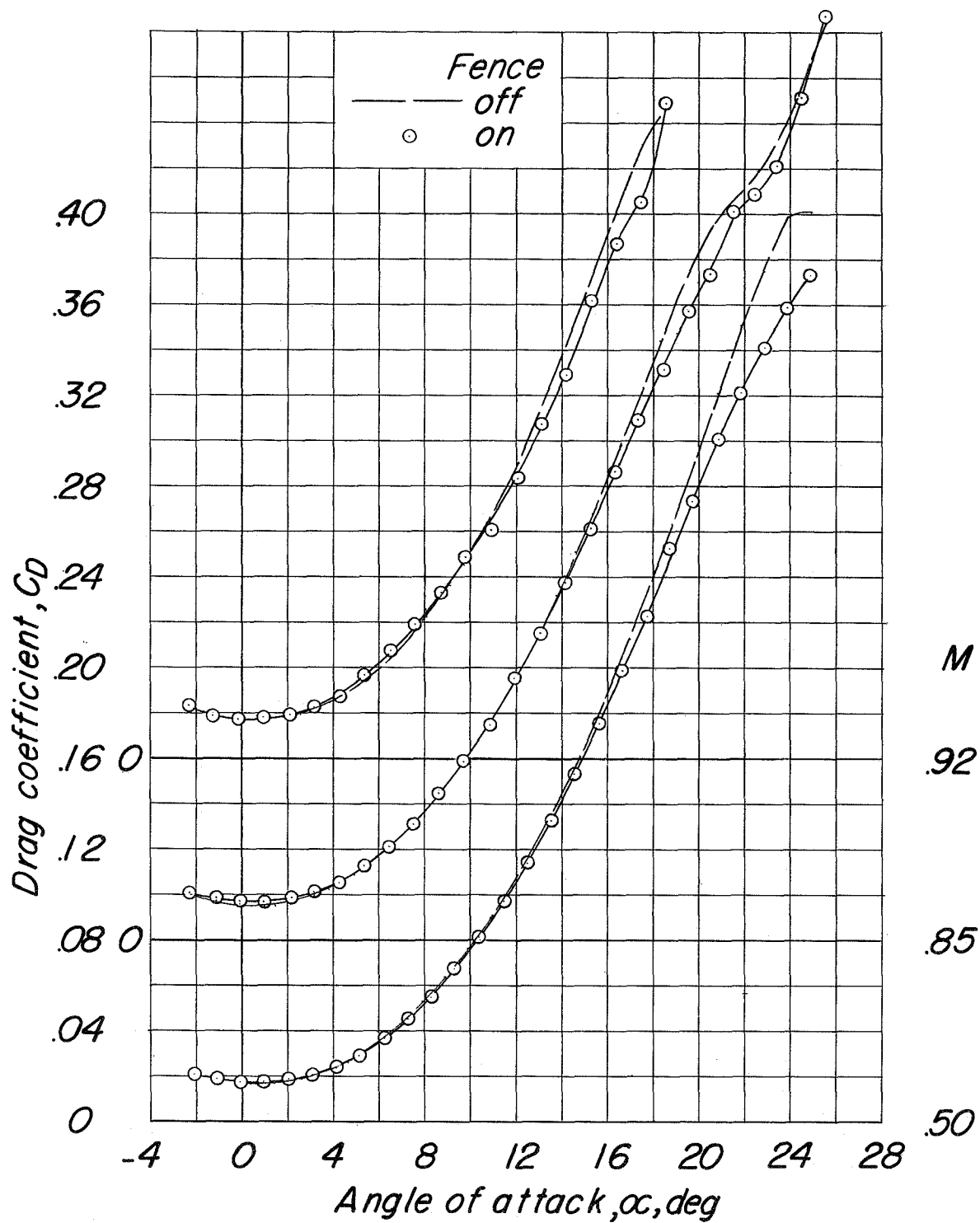
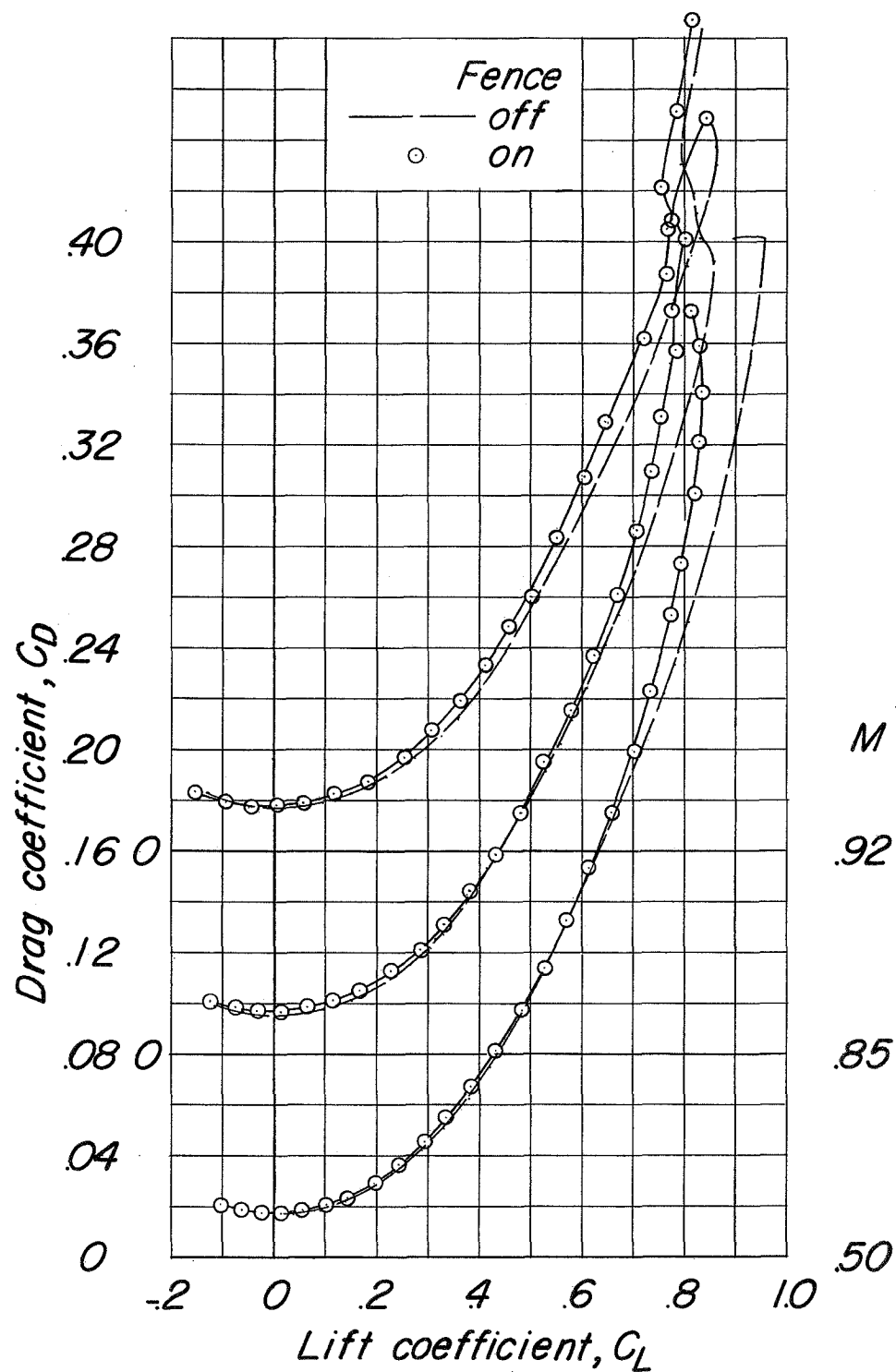
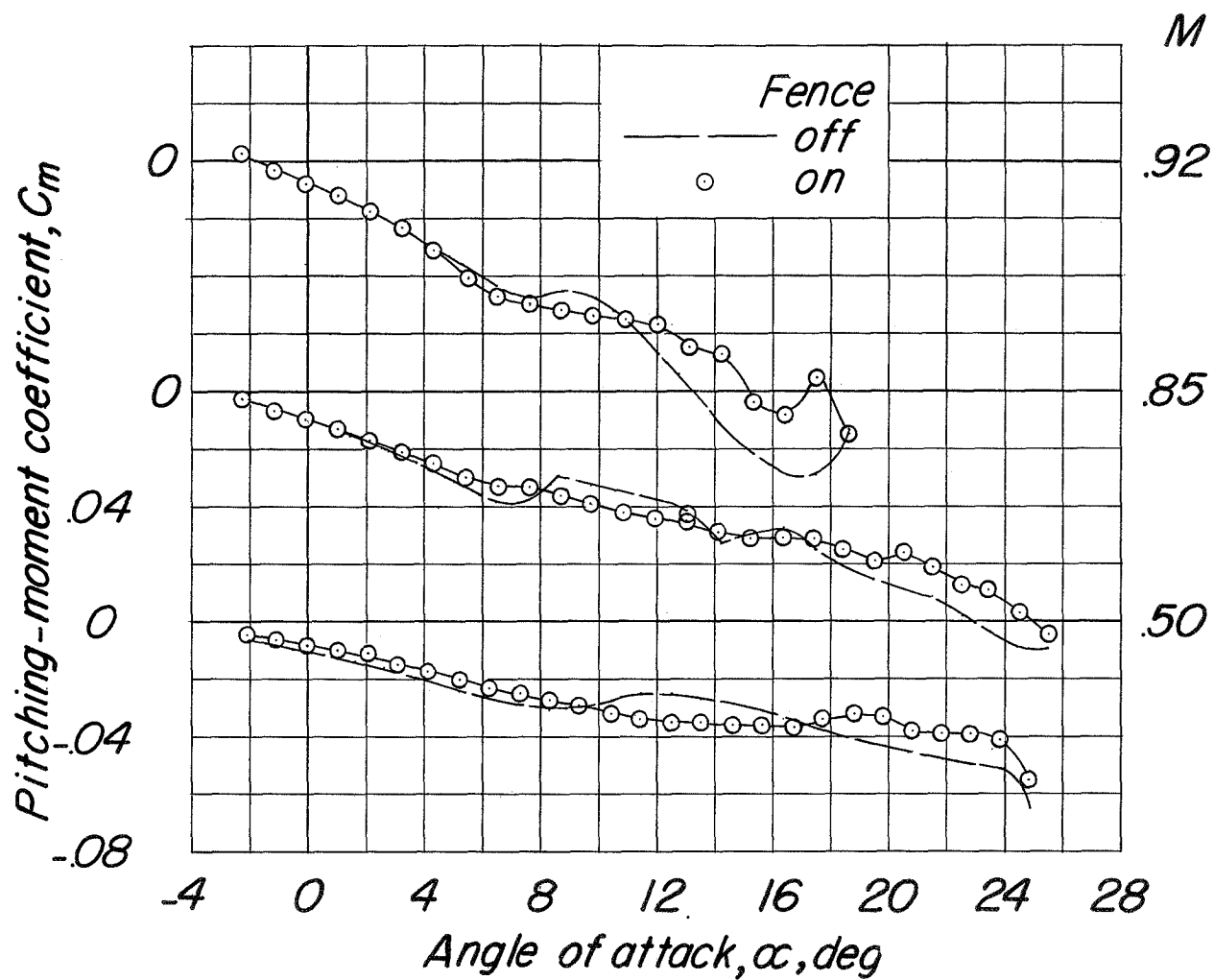
(b)  $C_D$  against  $\alpha$ .

Figure 13.- Continued.



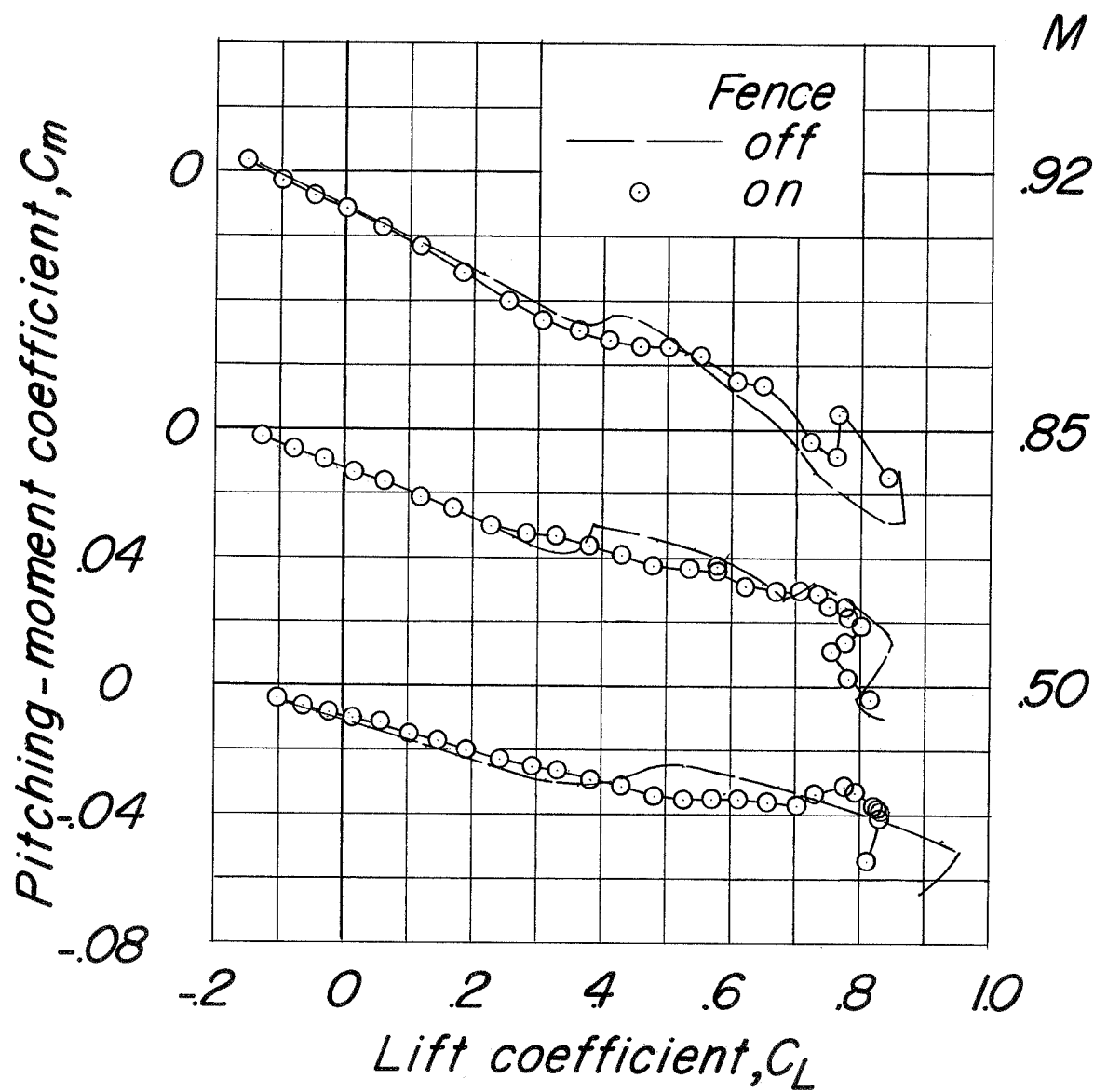
(c)  $C_D$  against  $C_L$ .

Figure 13.- Continued.



(d)  $C_m$  against  $\alpha$ .

Figure 13.- Continued.



(e)  $C_m$  against  $C_L$ .

Figure 13.- Concluded.

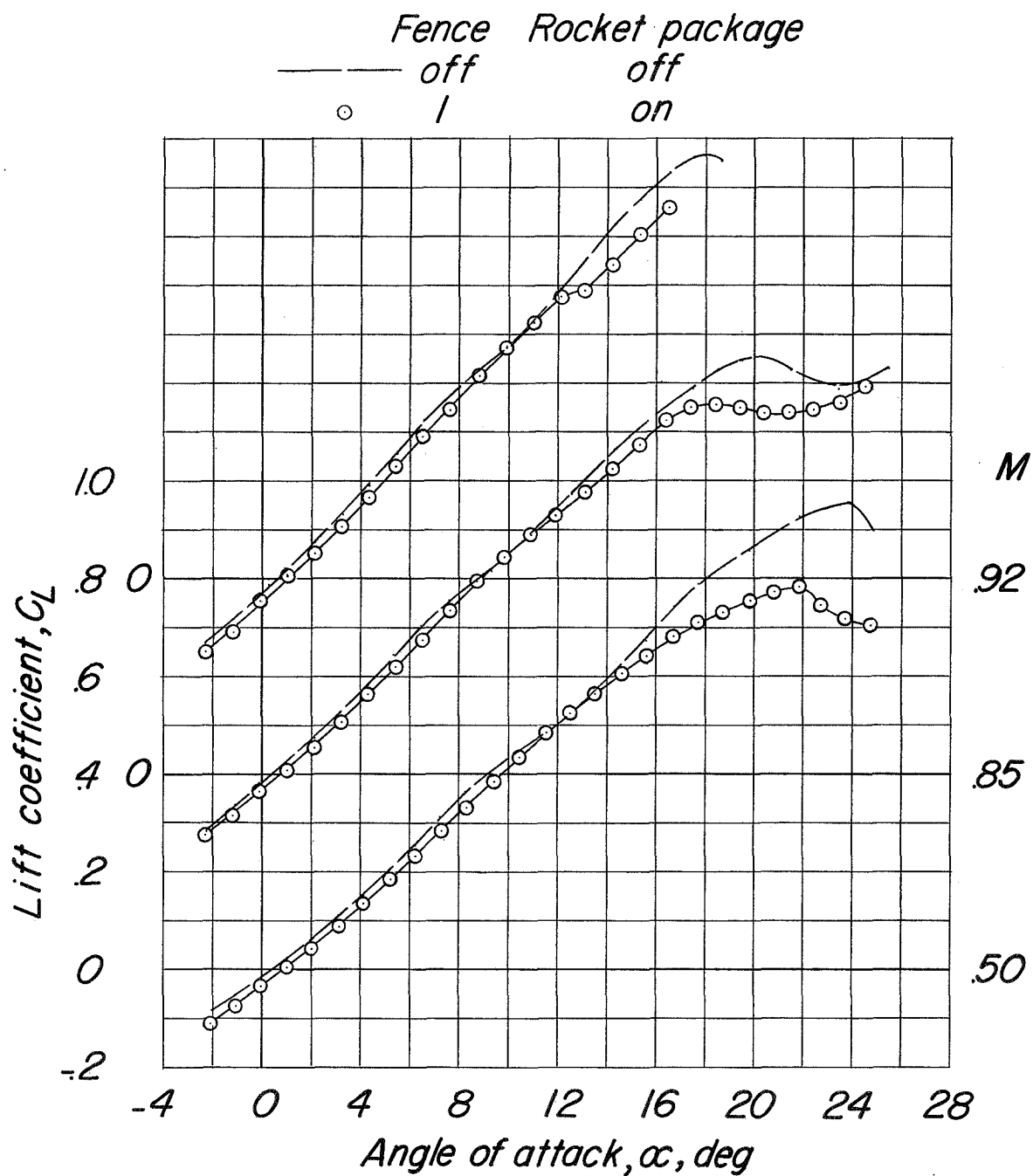
(a)  $C_L$  against  $\alpha$ .

Figure 14.- Basic longitudinal characteristics for configuration BCWV,  
 $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ , with and without fence 1 plus rocket package.

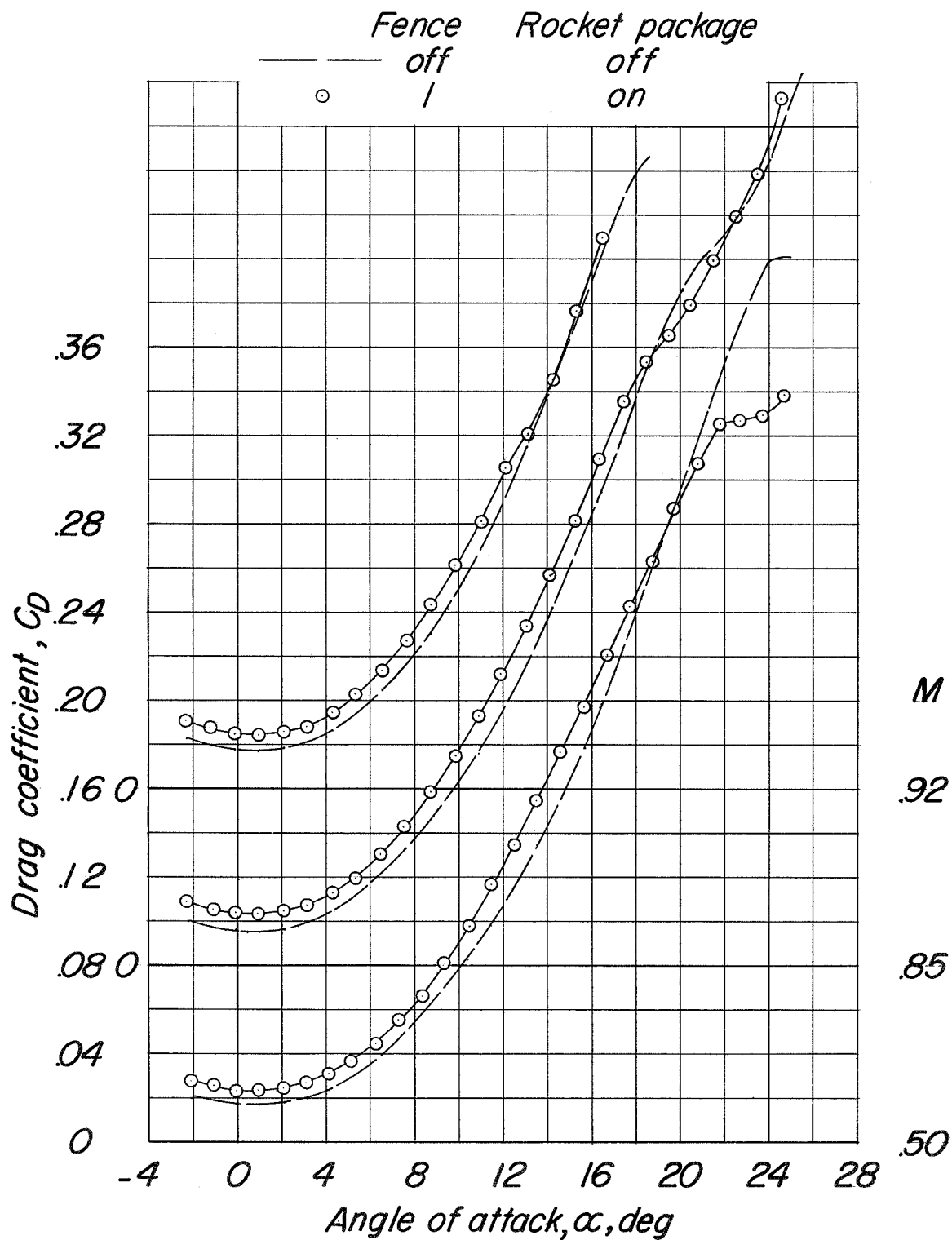
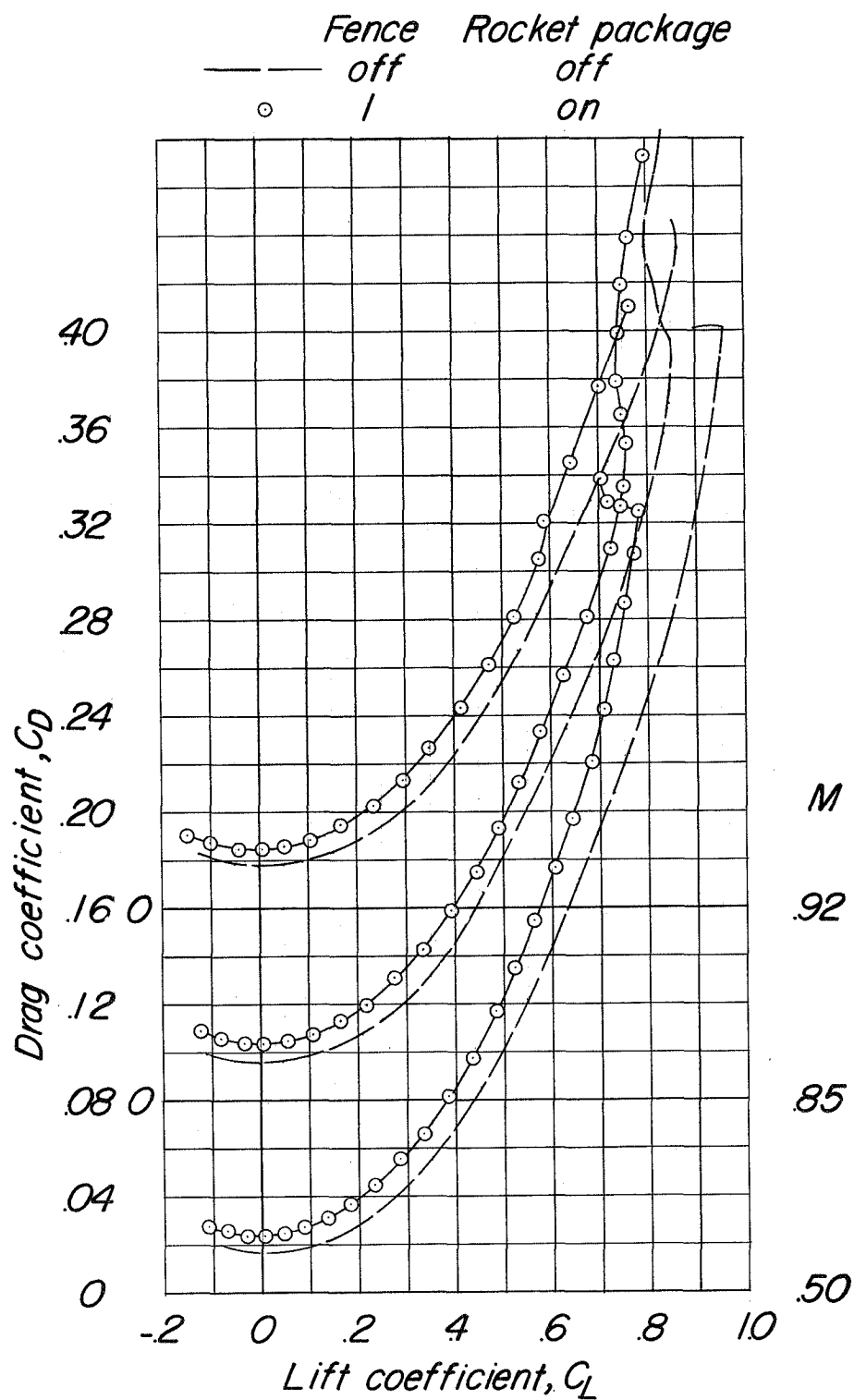
(b)  $C_D$  against  $\alpha$ .

Figure 14.- Continued.



(c)  $C_D$  against  $C_L$ .

Figure 14.- Continued.

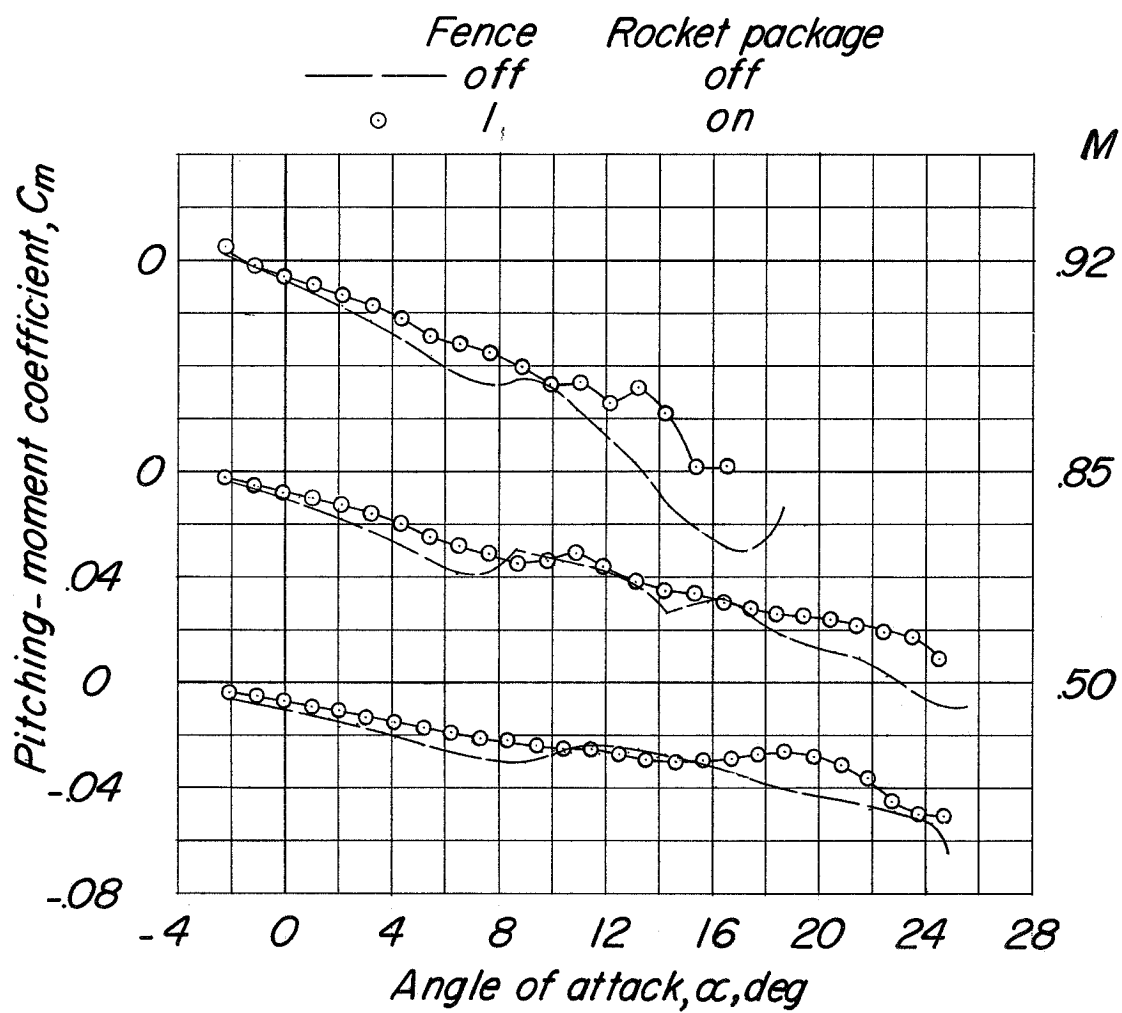
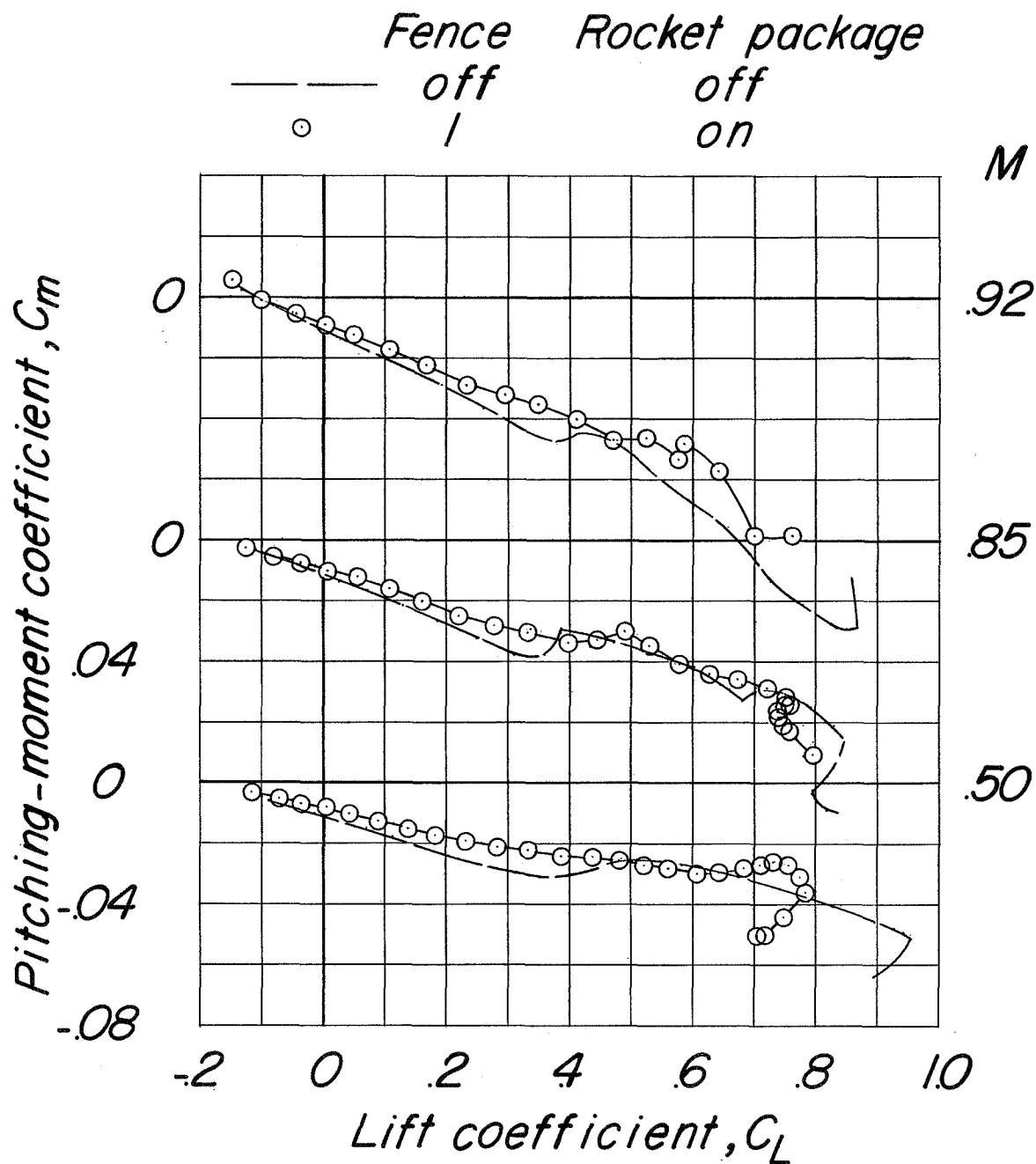
(d)  $C_m$  against  $\alpha$ .

Figure 14.- Continued.



(e)  $C_m$  against  $C_L$ .

Figure 14.- Concluded.

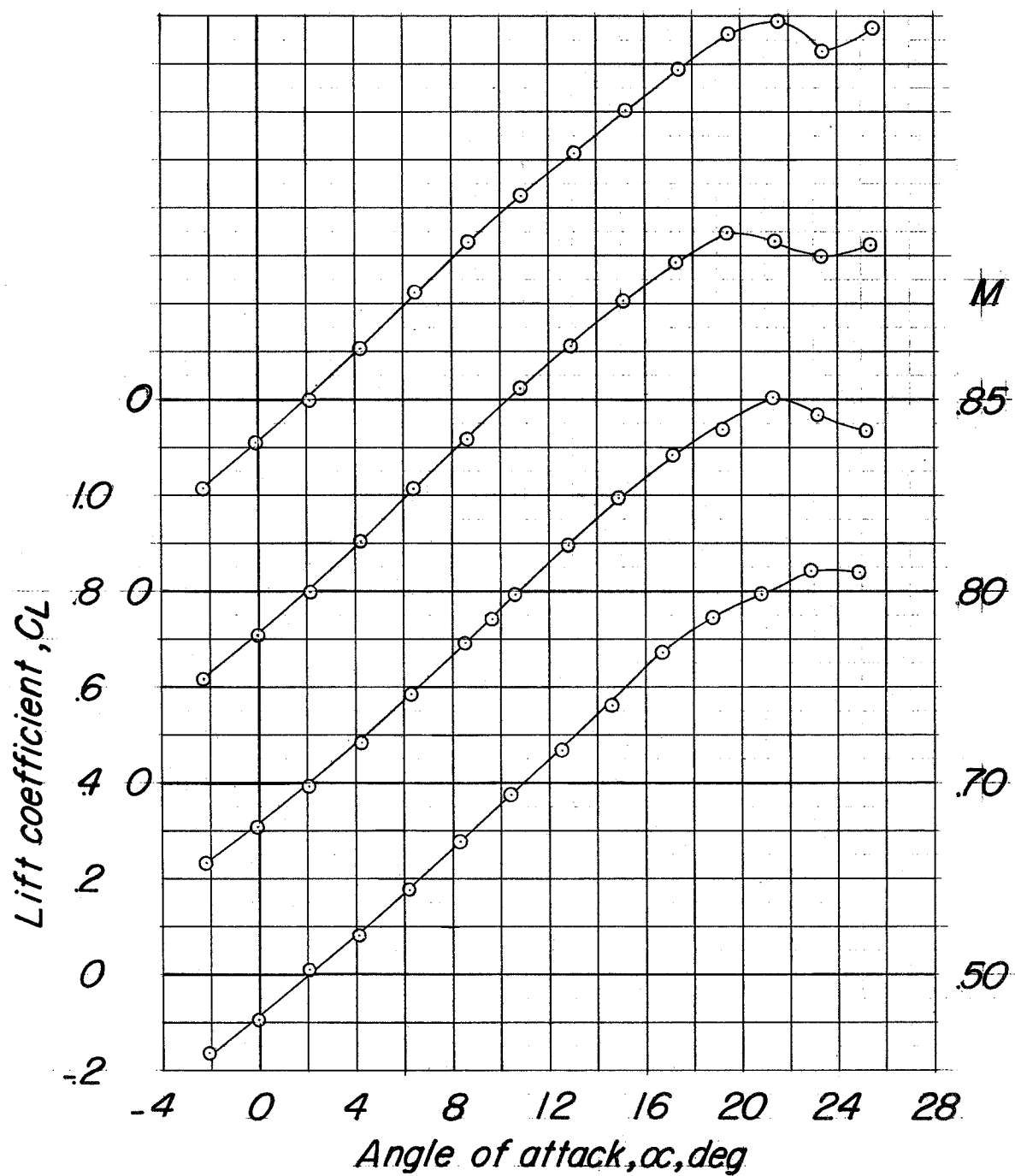
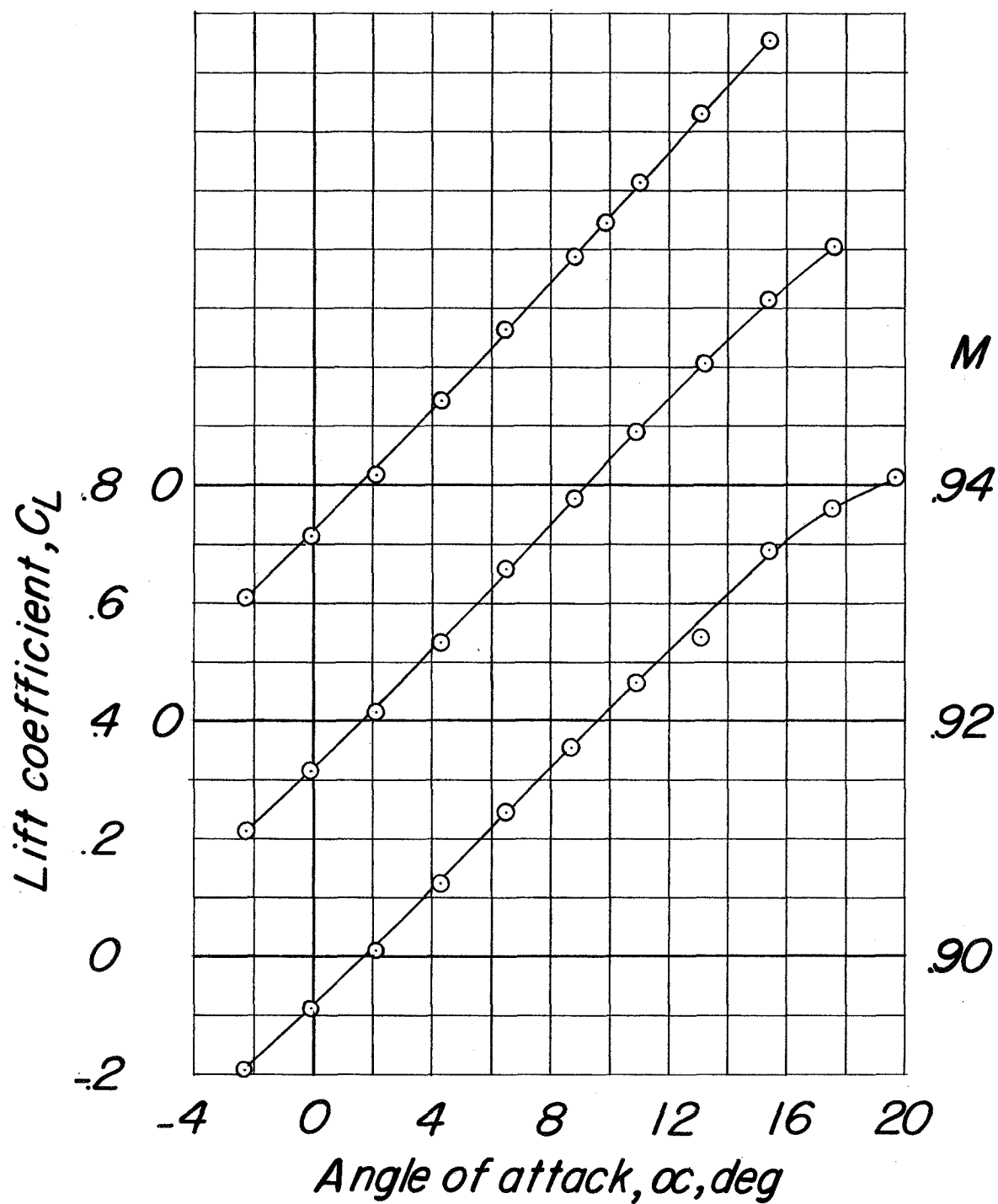
(a)  $C_L$  against  $\alpha$ .

Figure 15.- Basic longitudinal characteristics for configuration  $BCW_{F1} V$ ,  
 $\delta_e = 0^\circ$  right and  $-10^\circ$  left,  $\delta_r = 0^\circ$ .



(a) Concluded.

Figure 15.- Continued.

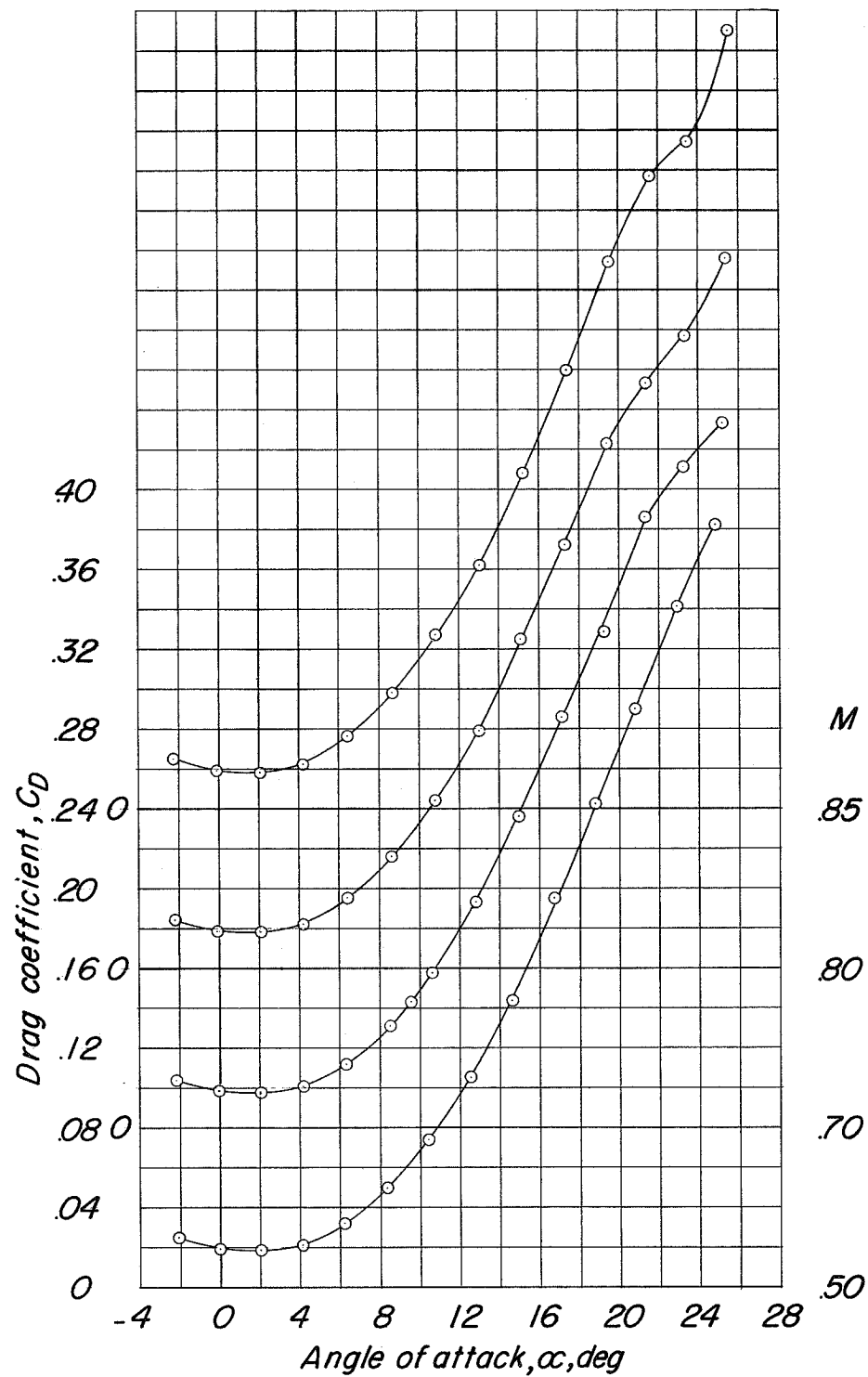
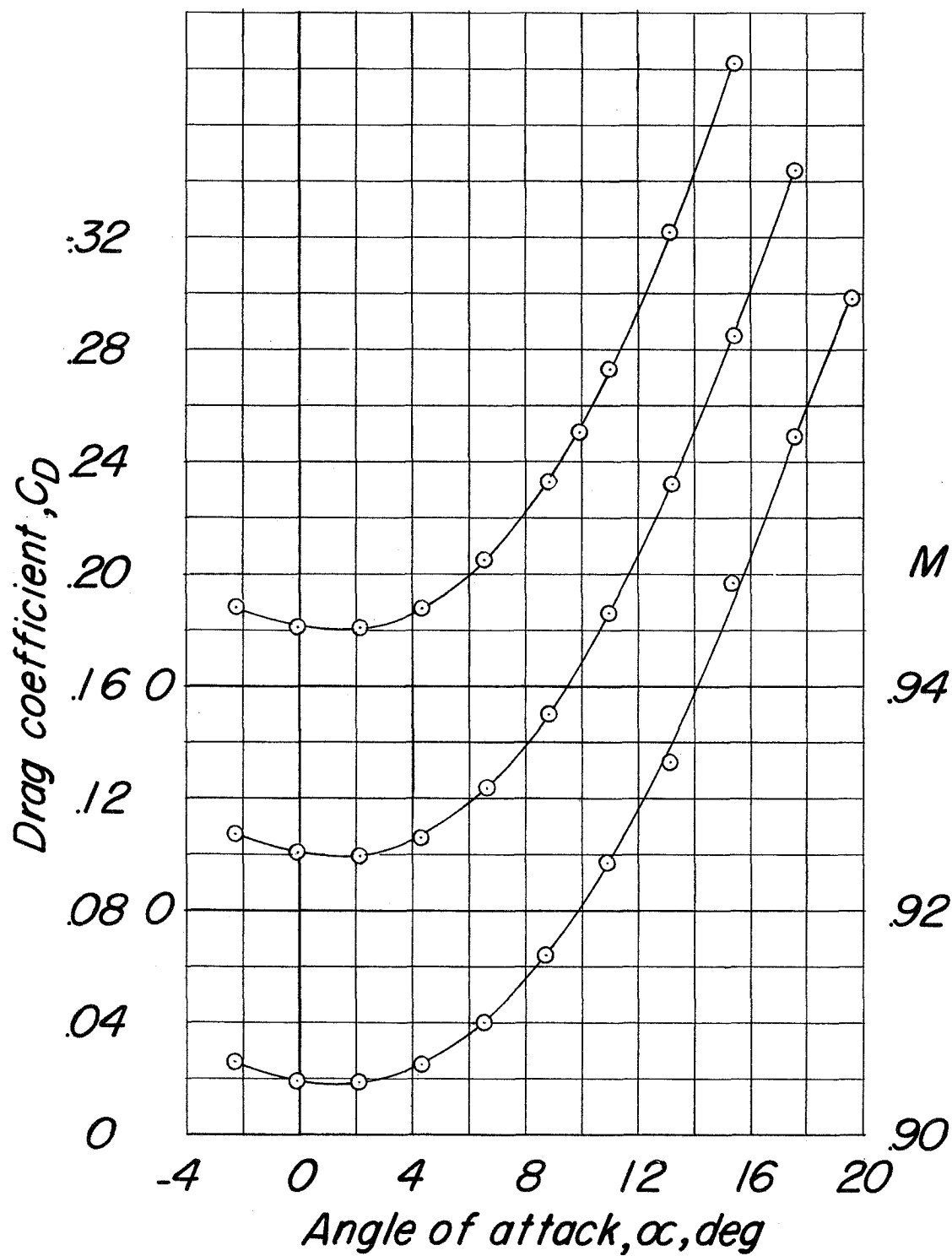
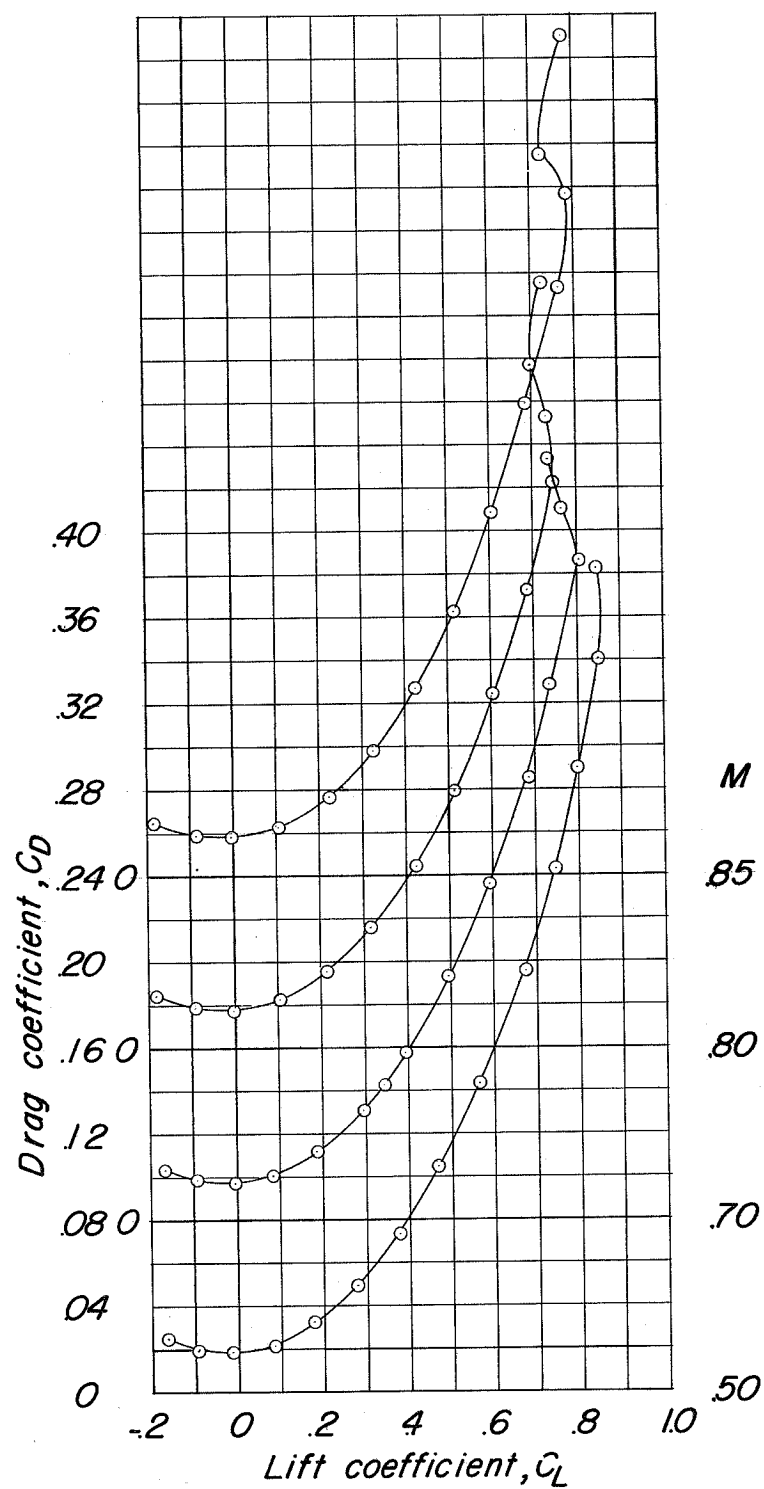
(b)  $C_D$  against  $\alpha$ .

Figure 15.- Continued.



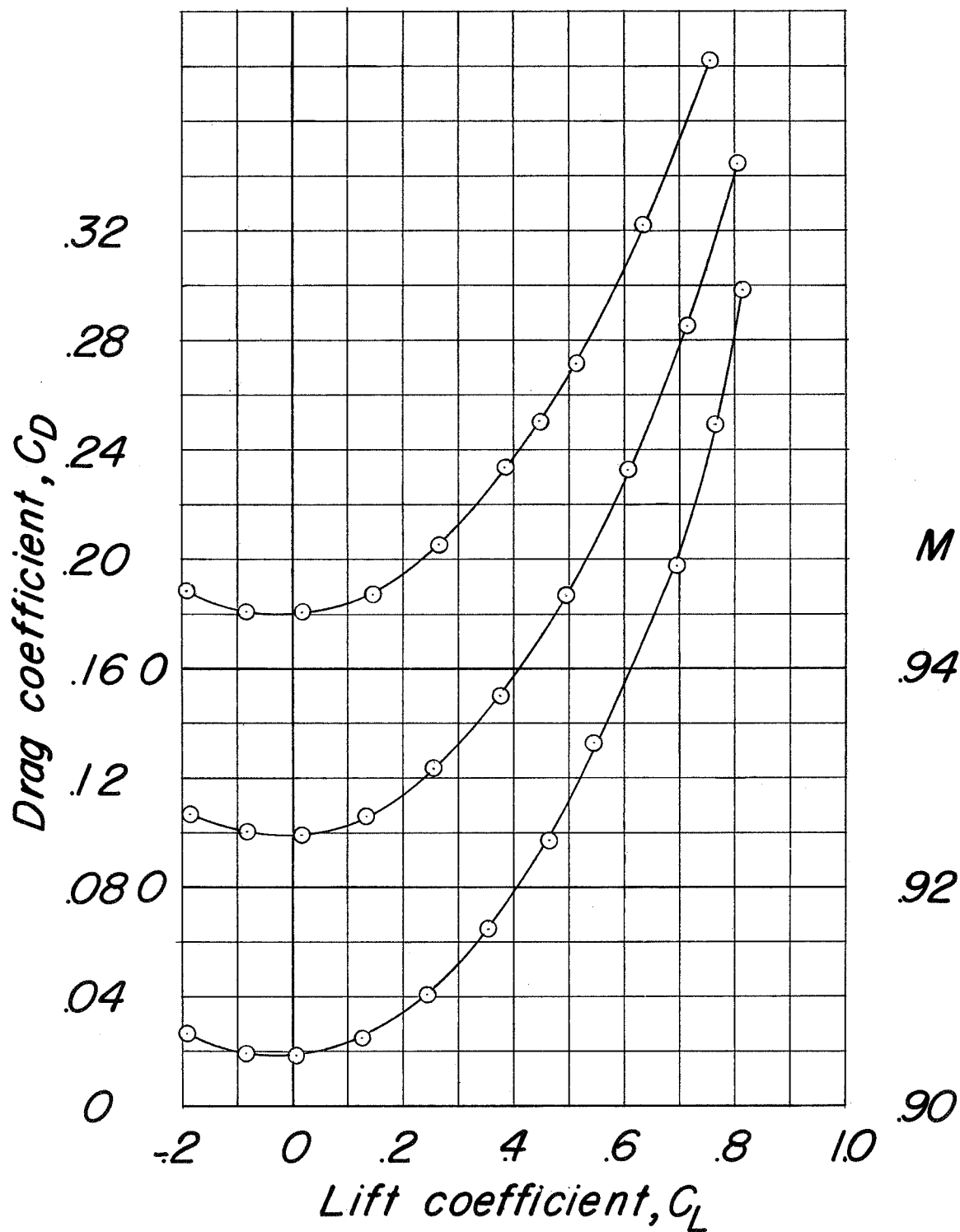
(b) Concluded.

Figure 15.- Continued.



(c)  $C_D$  against  $C_L$ .

Figure 15.- Continued.



(c) Concluded.

Figure 15.- Continued.

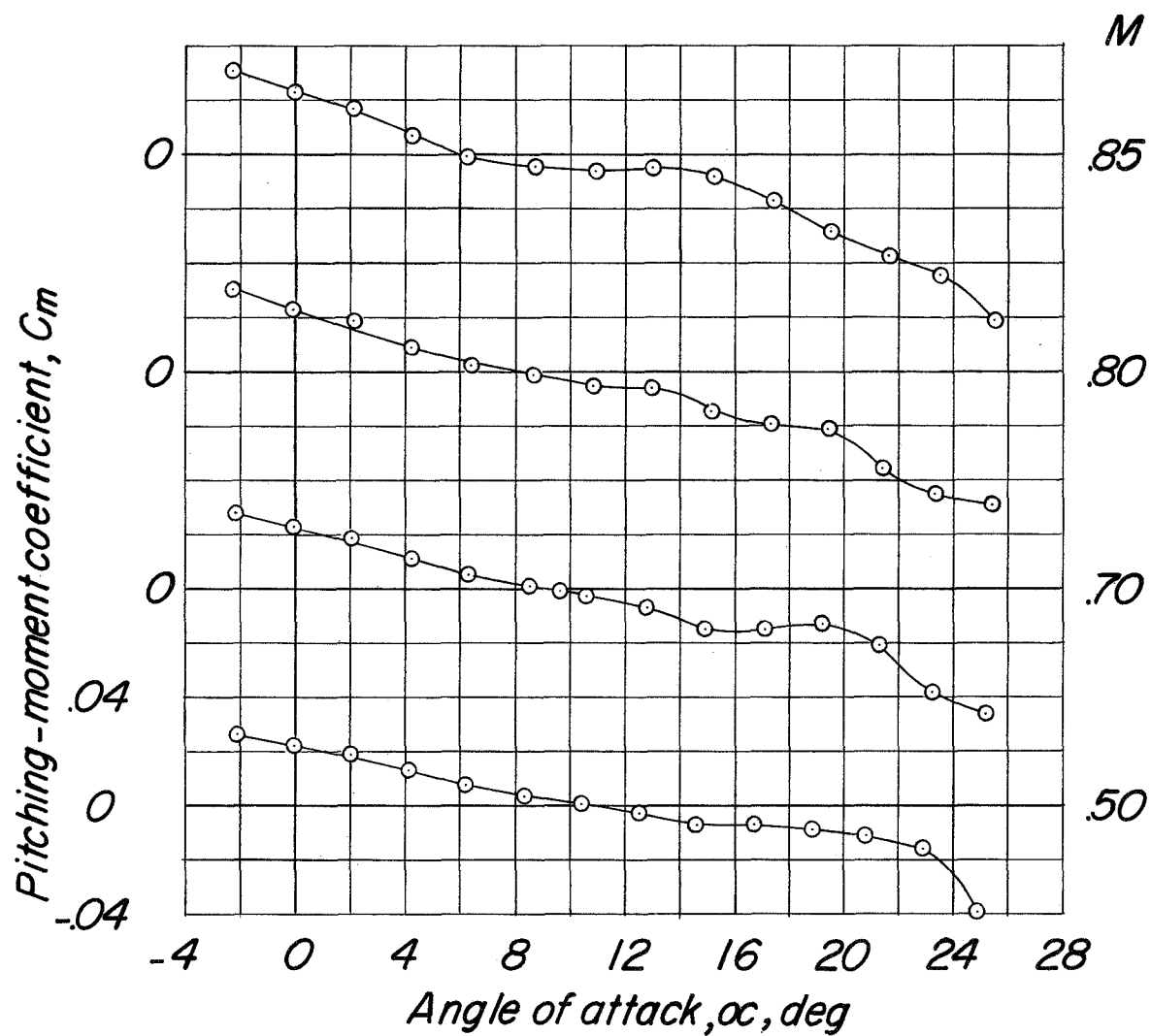
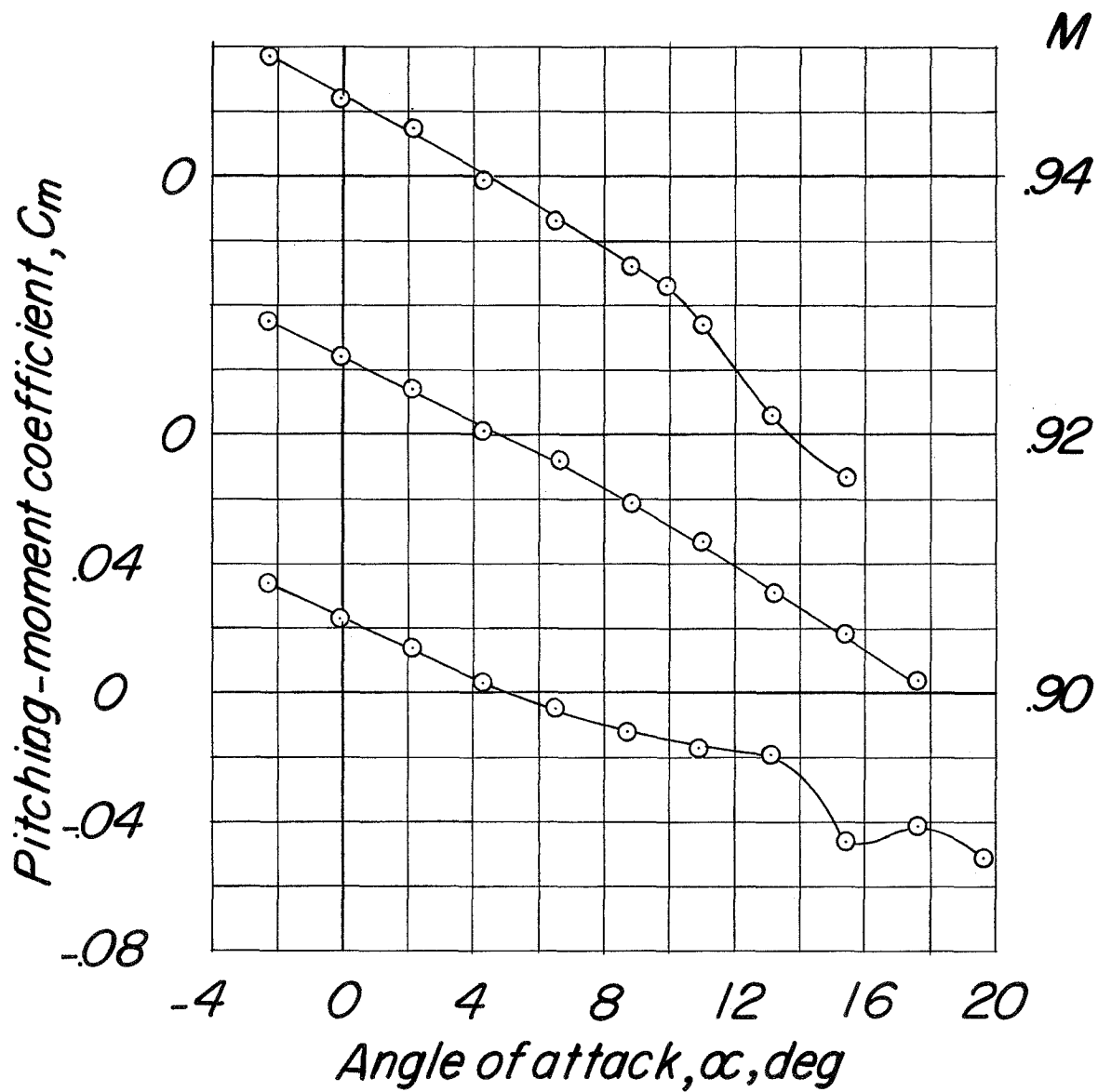
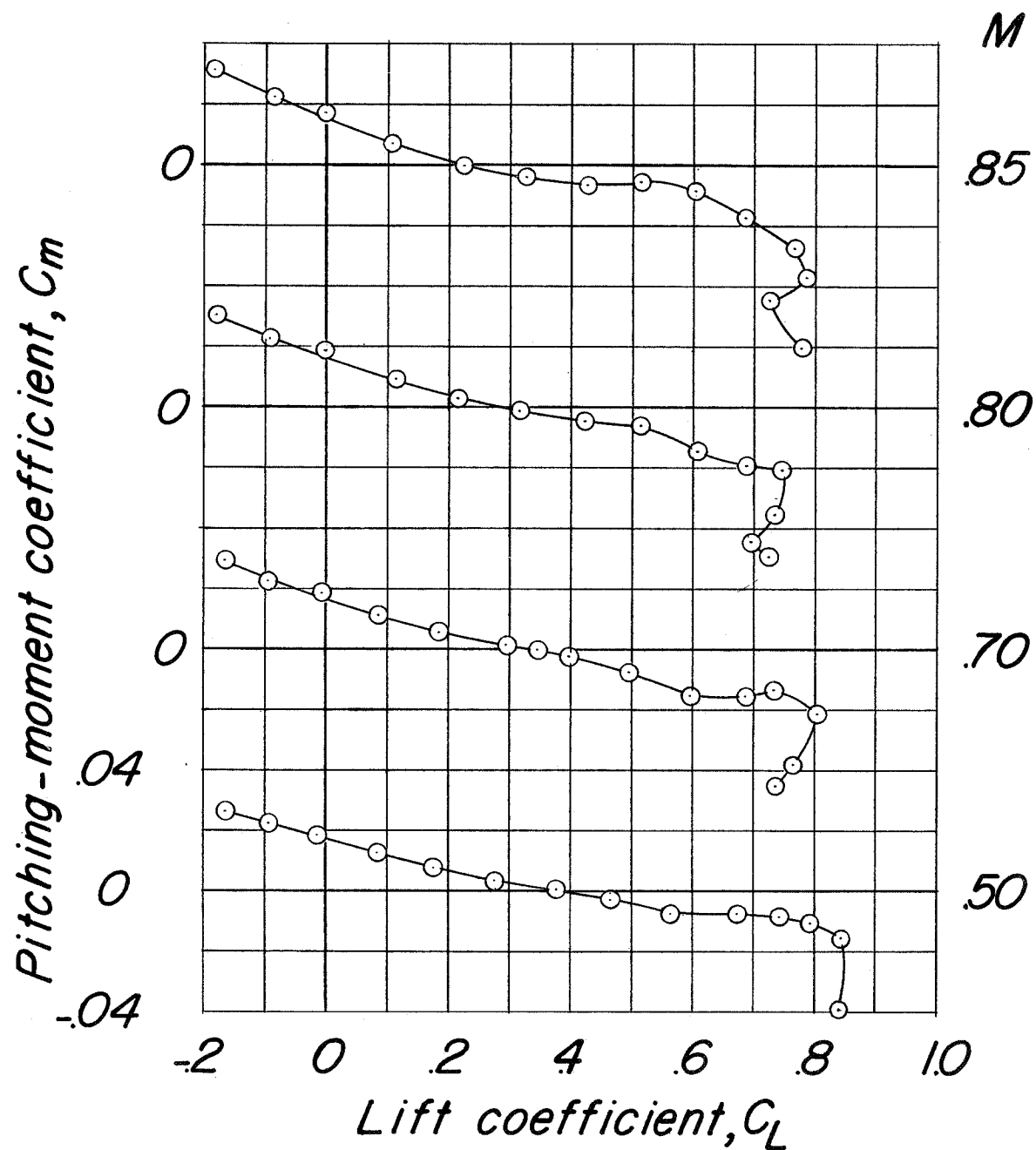
(d)  $C_m$  against  $\alpha$ .

Figure 15.- Continued.



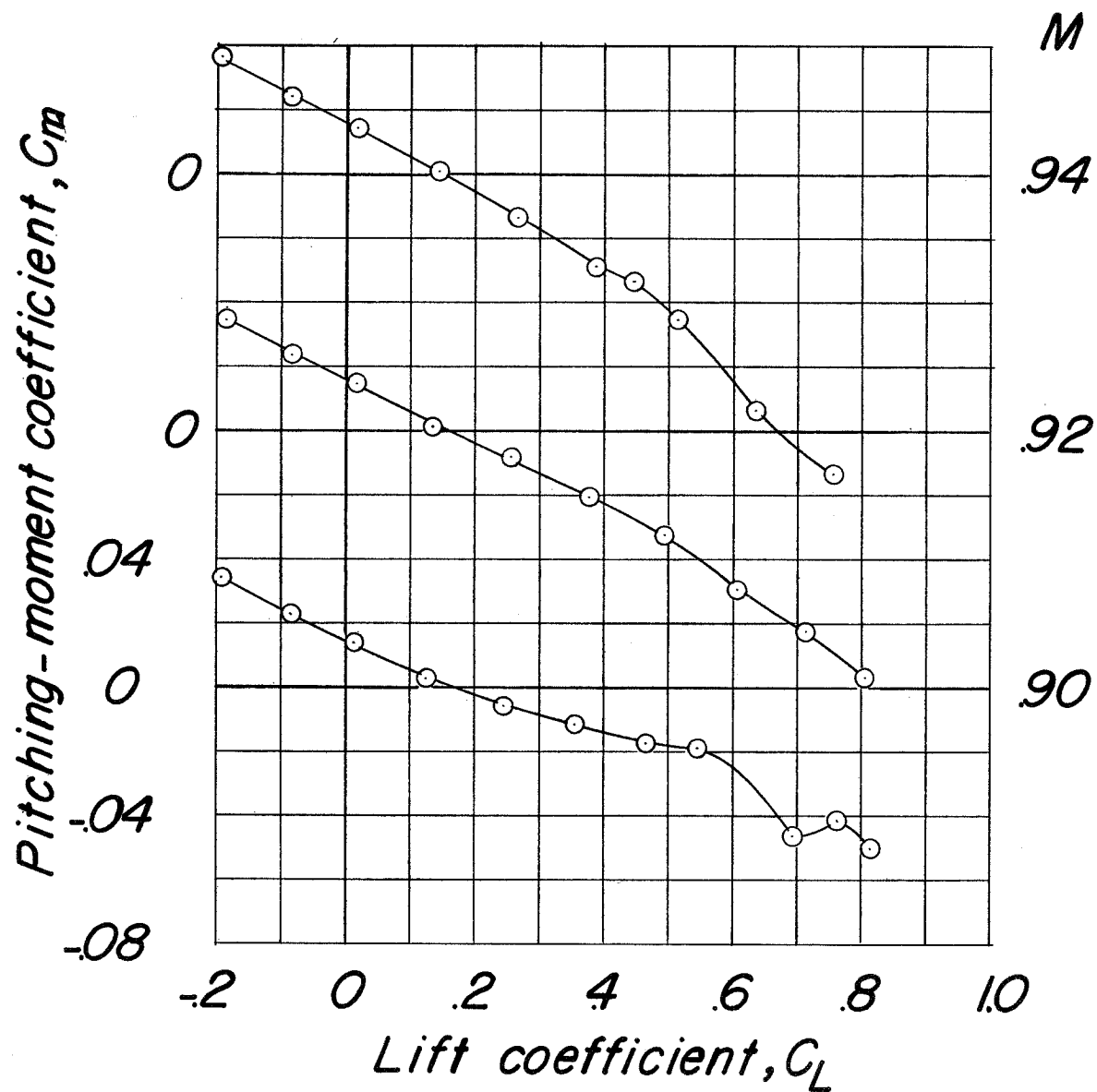
(d) Concluded.

Figure 15.- Continued.



(e)  $C_m$  against  $C_L$ .

Figure 15.- Continued.



(e) Concluded.

Figure 15.- Concluded.

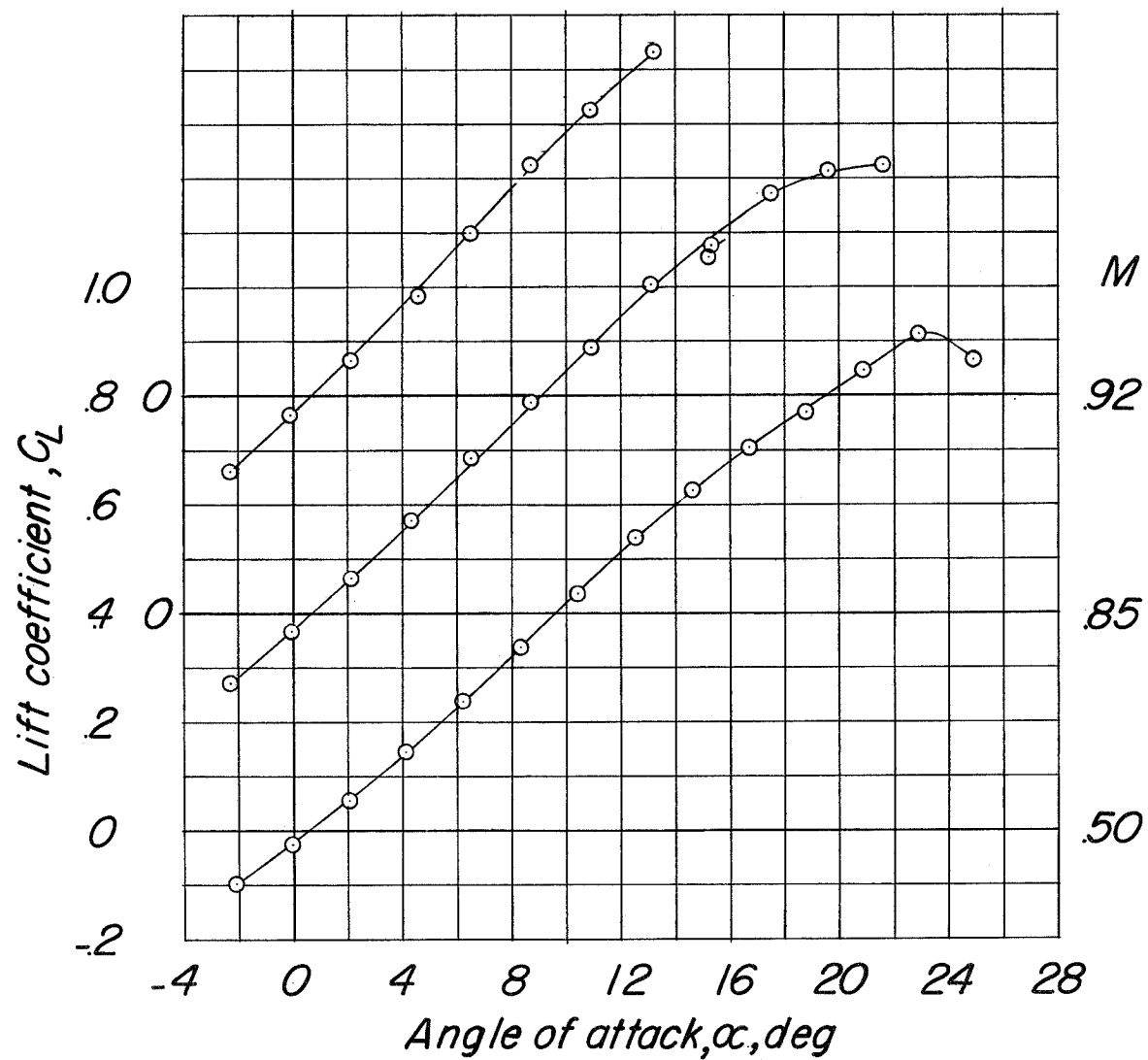
(a)  $C_L$  against  $\alpha$ .

Figure 16.- Basic longitudinal characteristics for configuration  $BCW_{F_1} V$ ,  
 $\delta_r = 10^\circ$ ,  $\delta_e = 0^\circ$ .

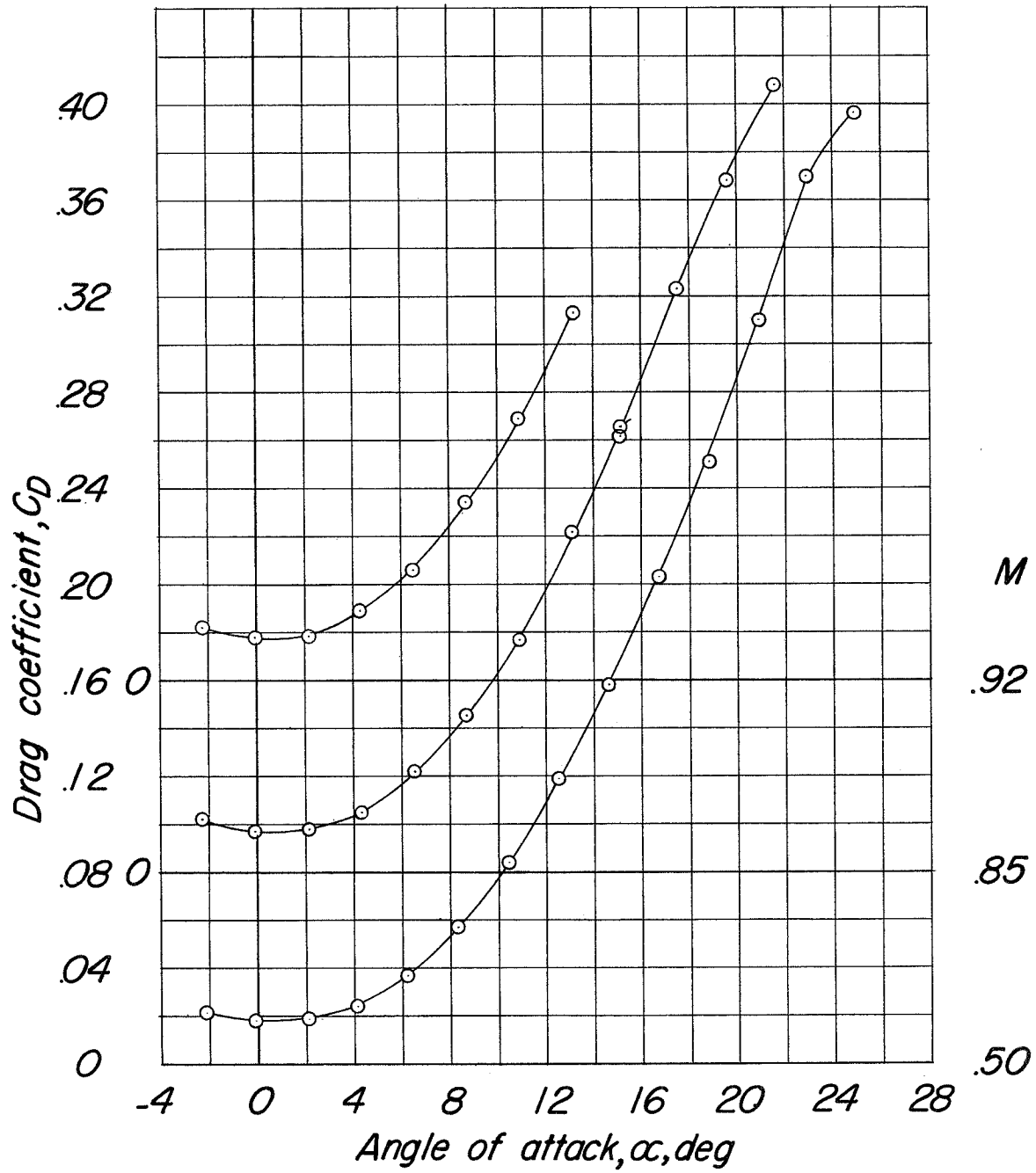
(b)  $C_D$  against  $\alpha$ .

Figure 16.- Continued.

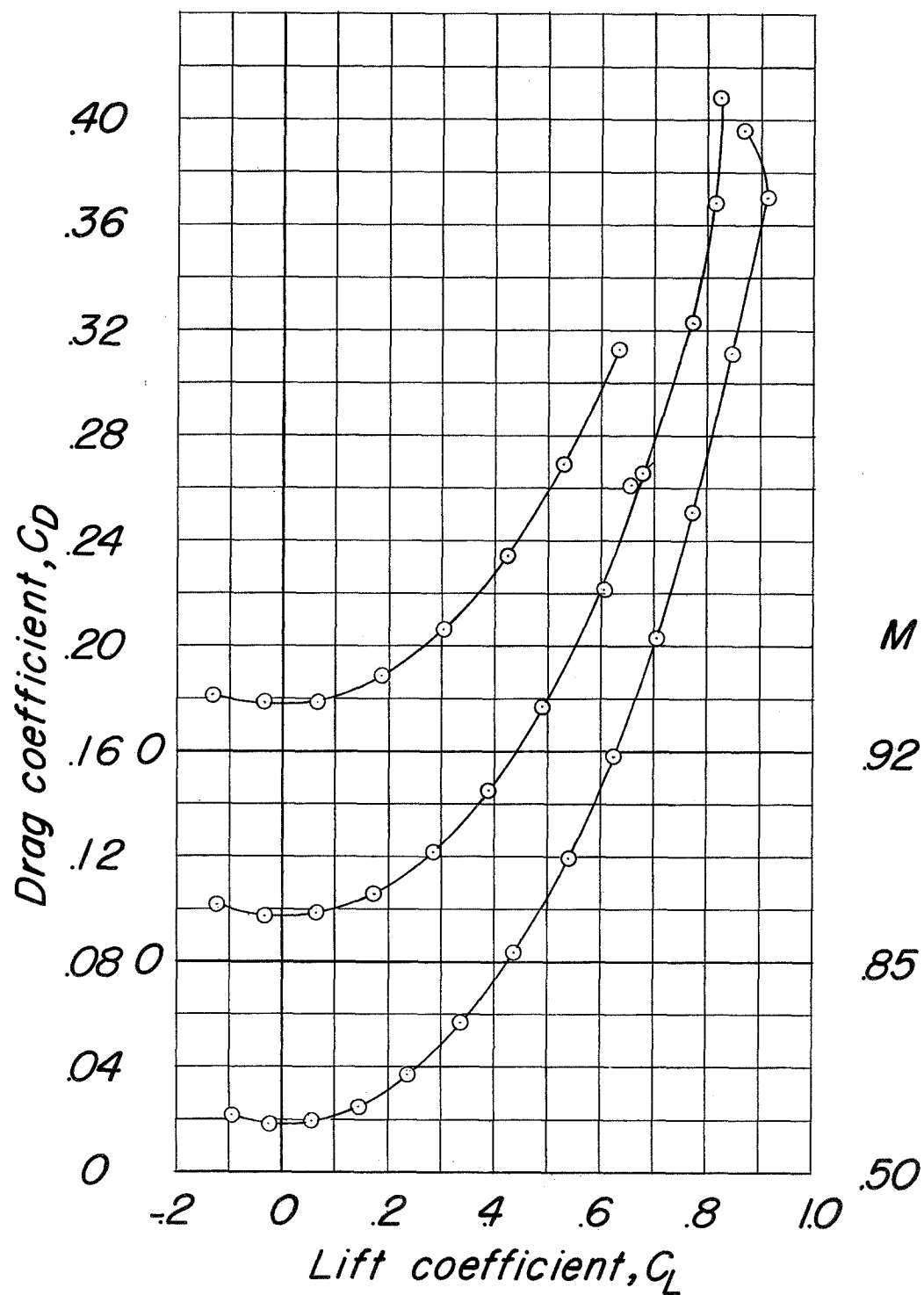
(c)  $C_D$  against  $C_L$ .

Figure 16.- Continued.

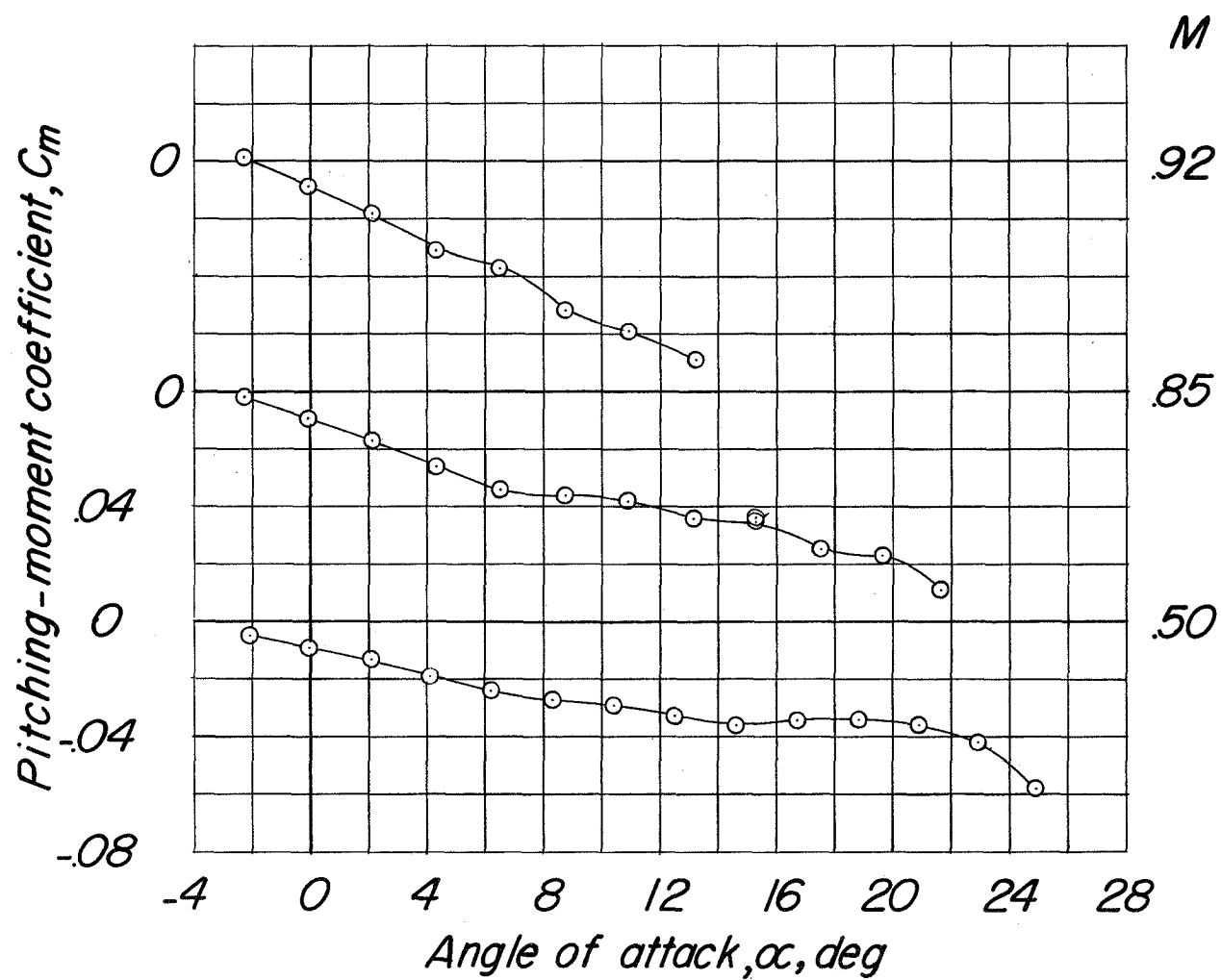
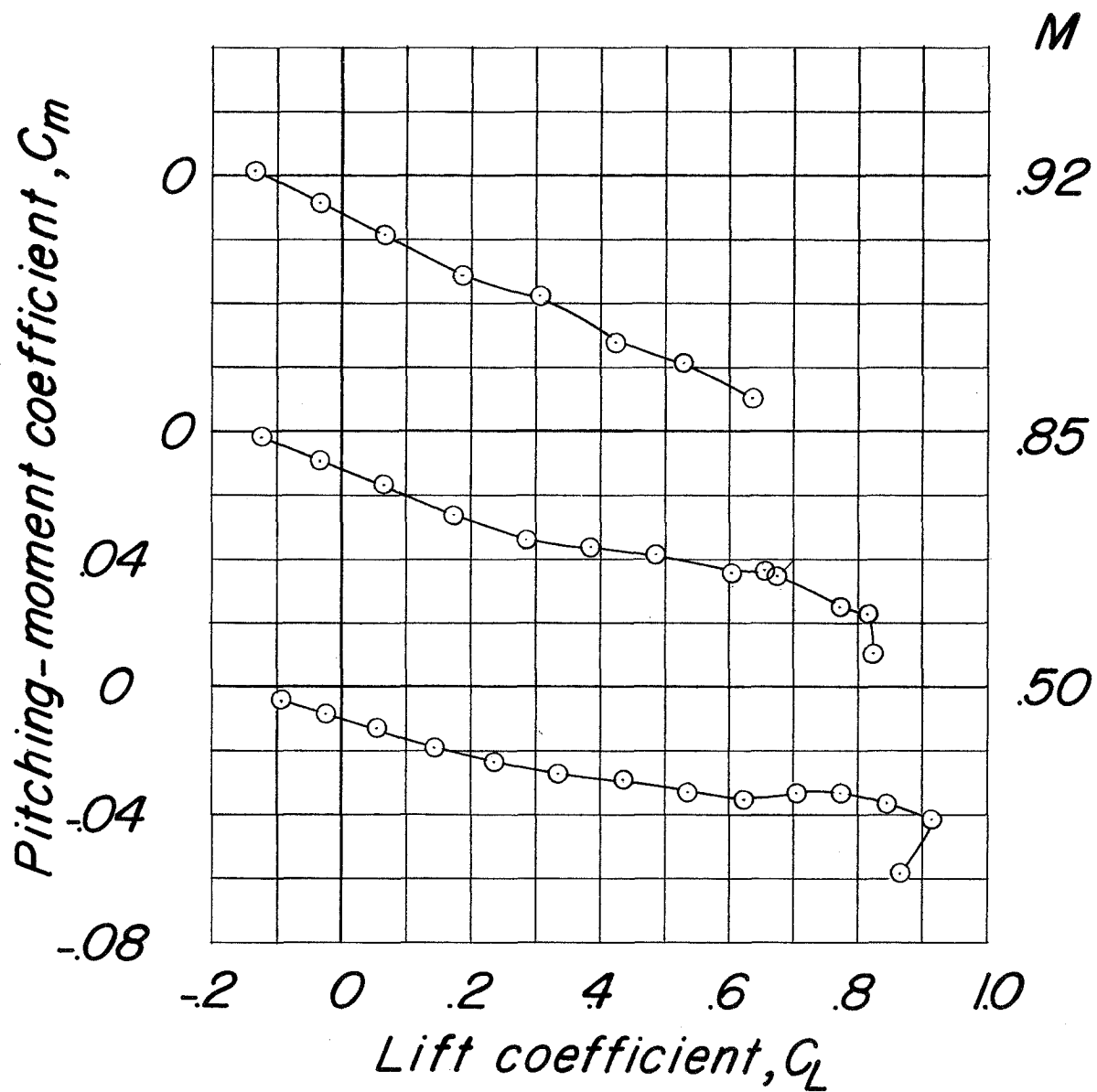
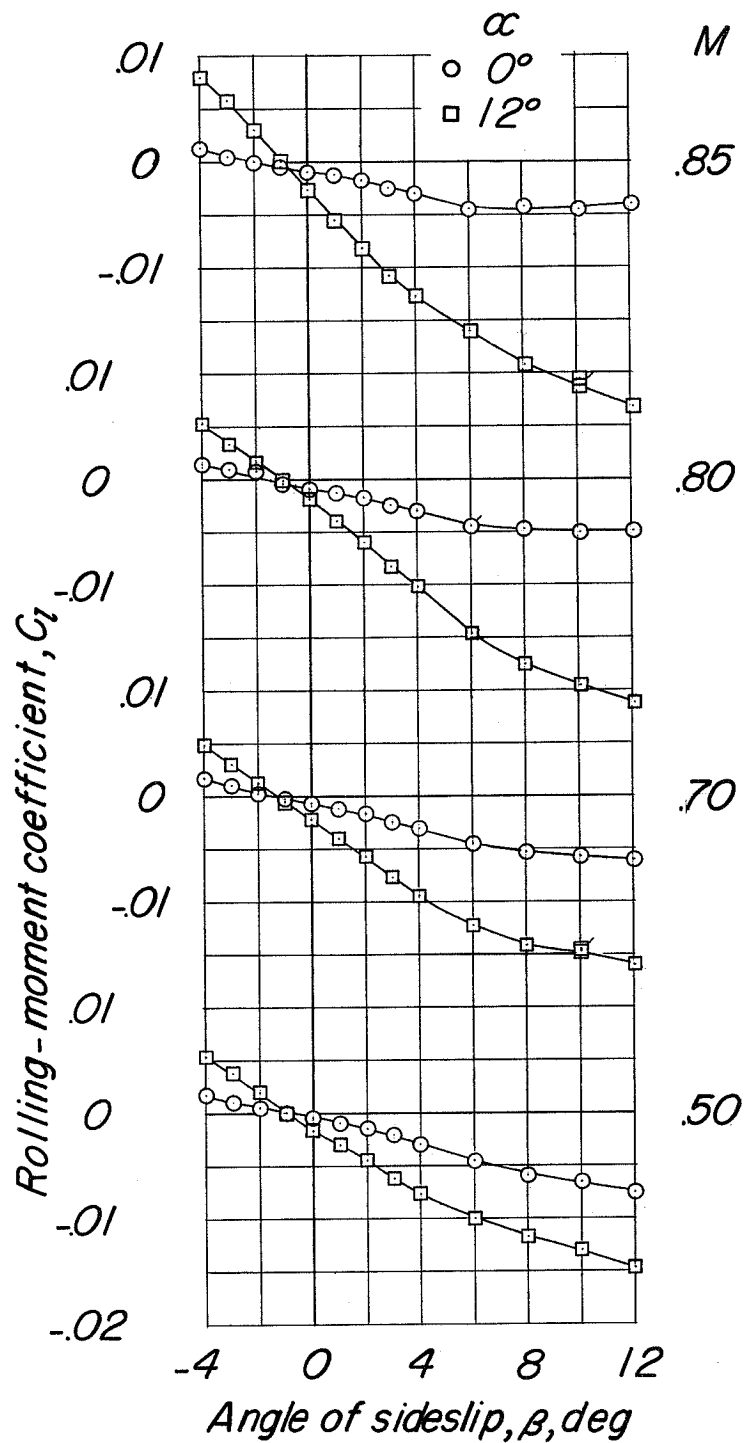
(d)  $C_m$  against  $\alpha$ .

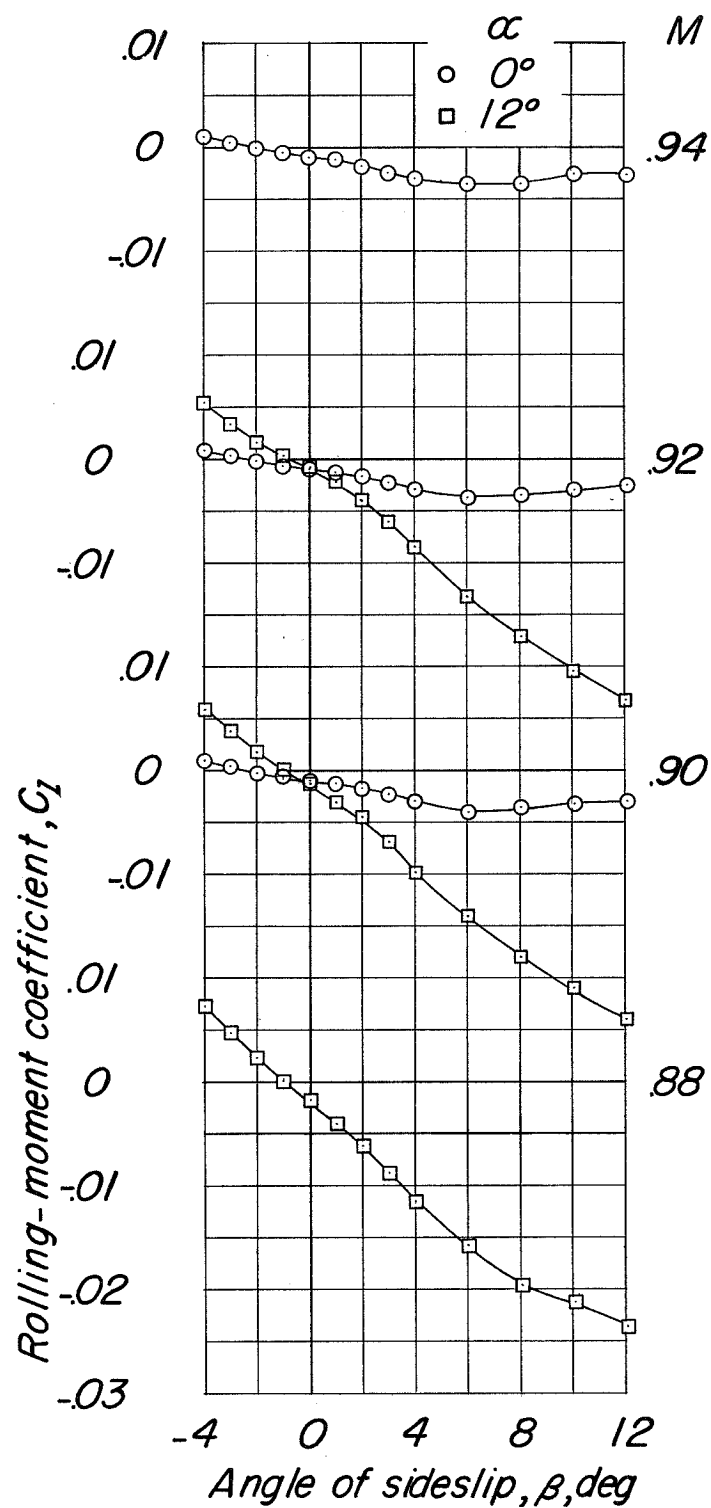
Figure 16.- Continued.



(e)  $C_m$  against  $C_L$ .

Figure 16.- Concluded.

(a)  $C_l$  against  $\beta$ .Figure 17.- Variation of lateral coefficients with angle of sideslip for configuration BCWV,  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ .



(a) Concluded.

Figure 17.- Continued.

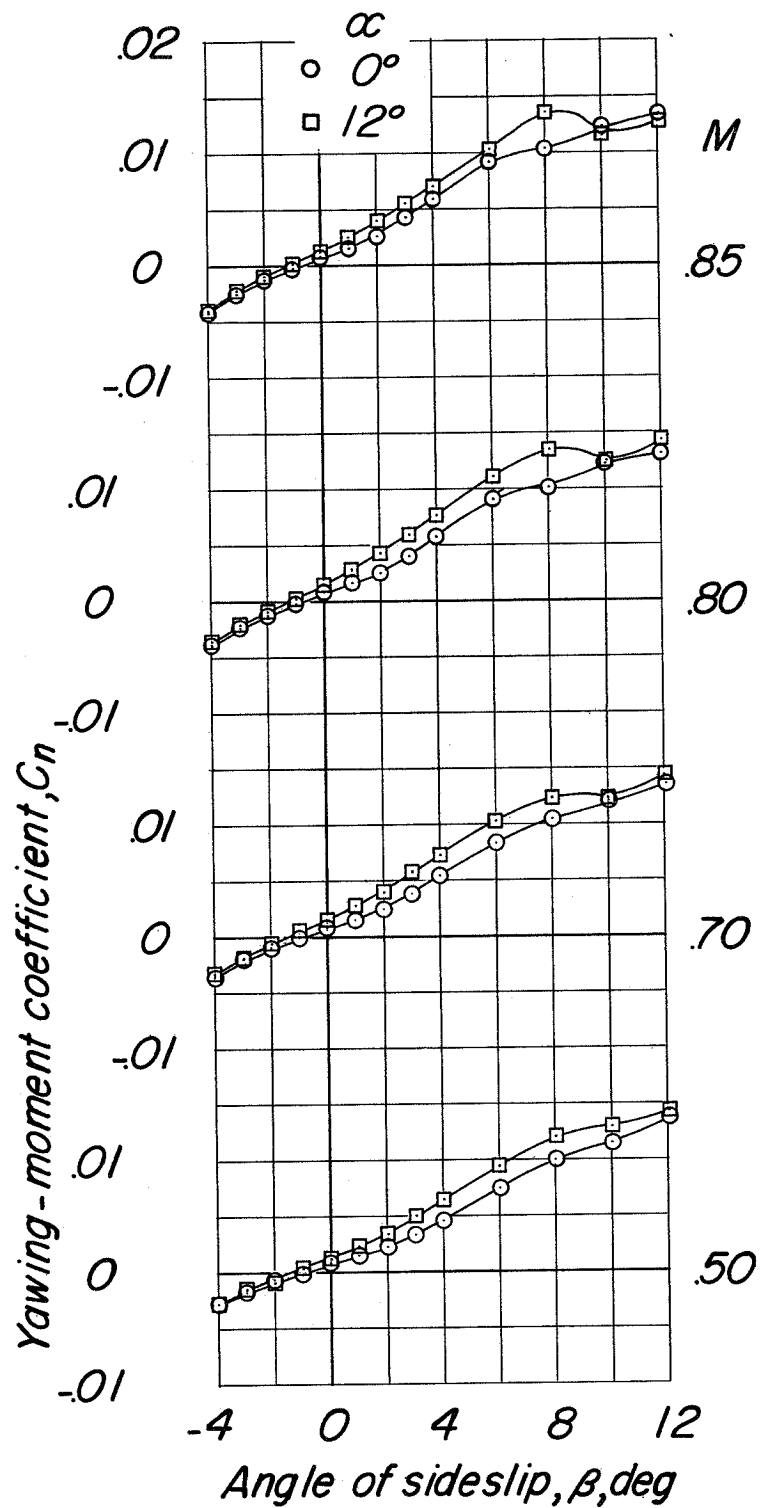
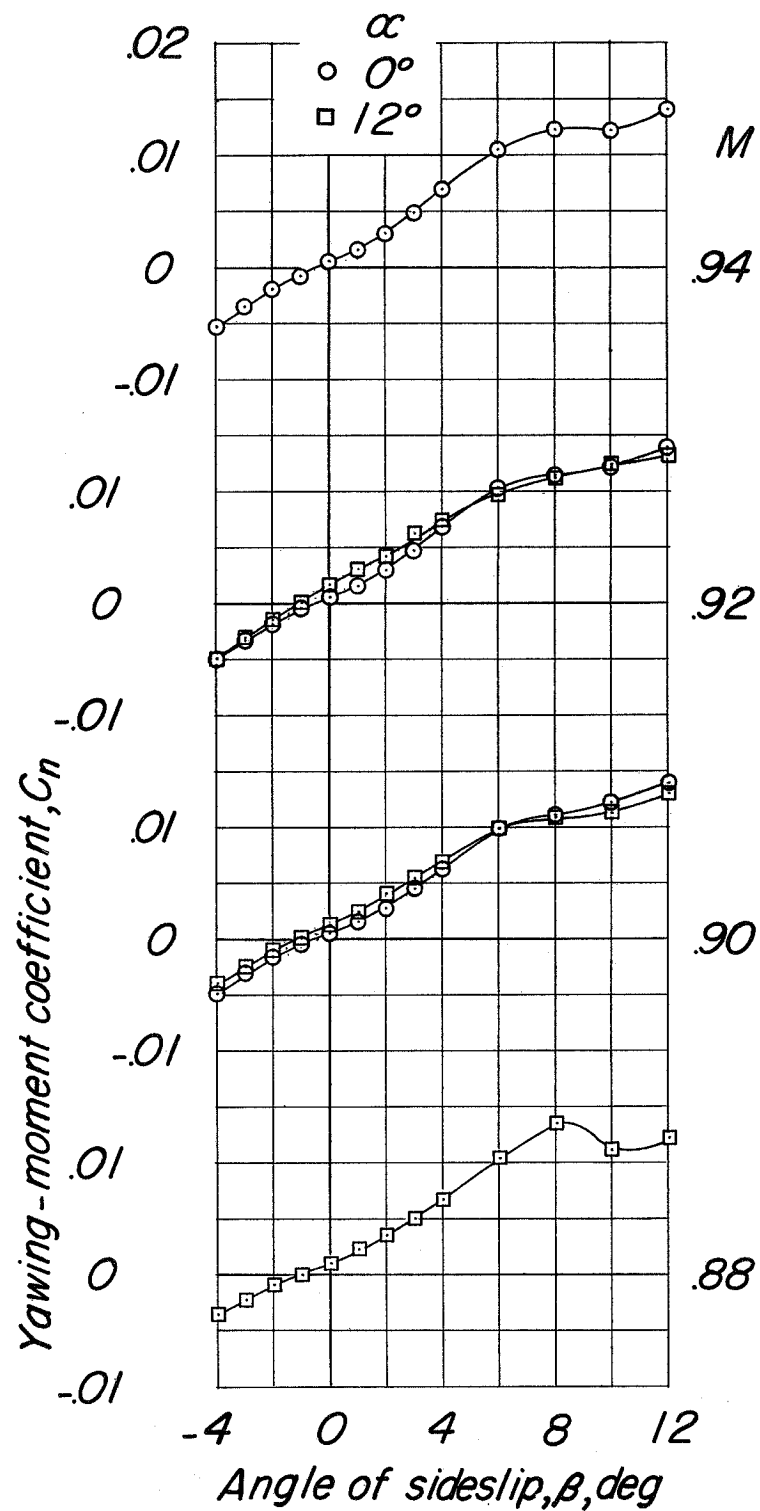
(b)  $C_n$  against  $\beta$ .

Figure 17.- Continued.



(b) Concluded.

Figure 17.- Continued.

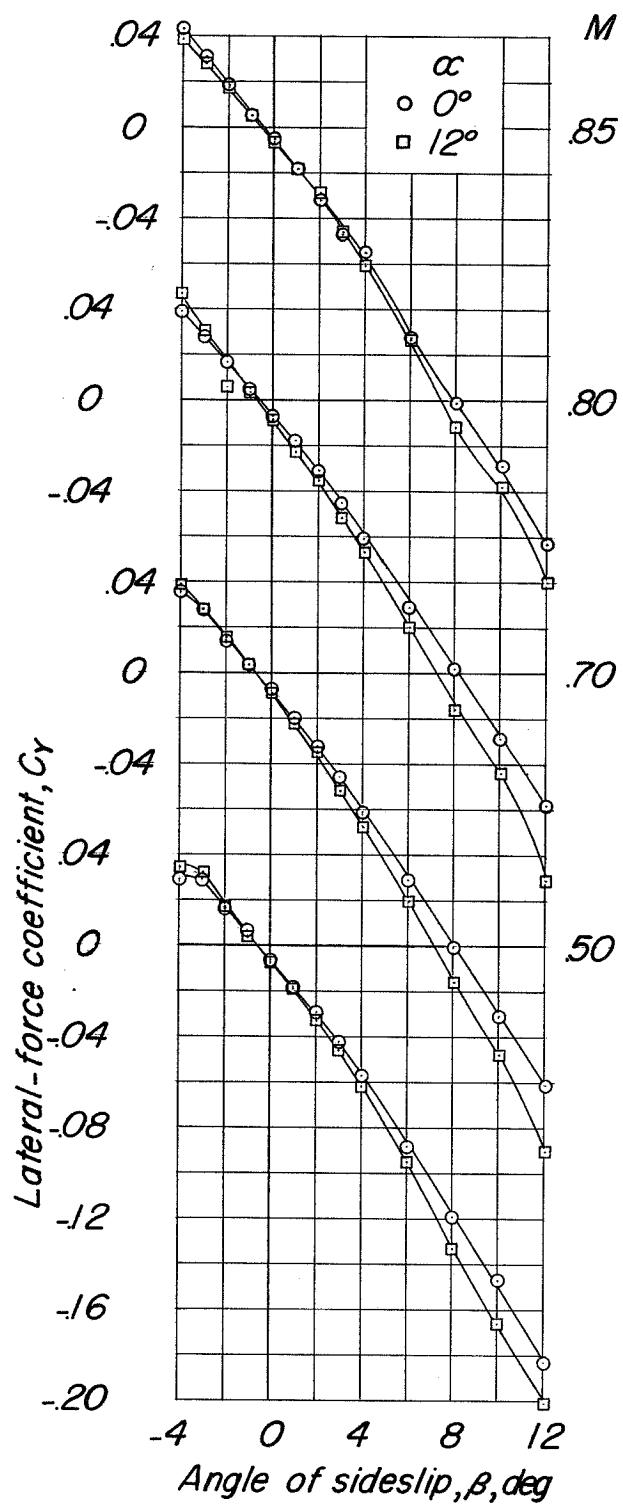
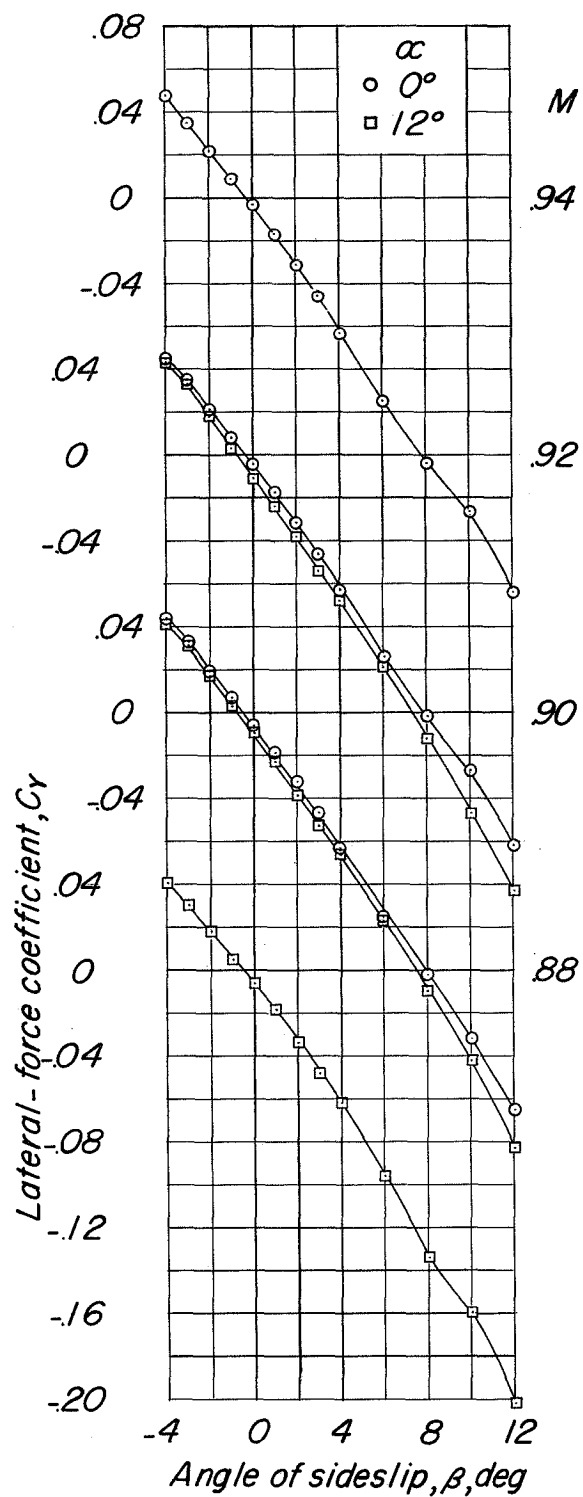
(c)  $C_Y$  against  $\beta$ .

Figure 17.- Continued.



(c) Concluded.

Figure 17.- Concluded.

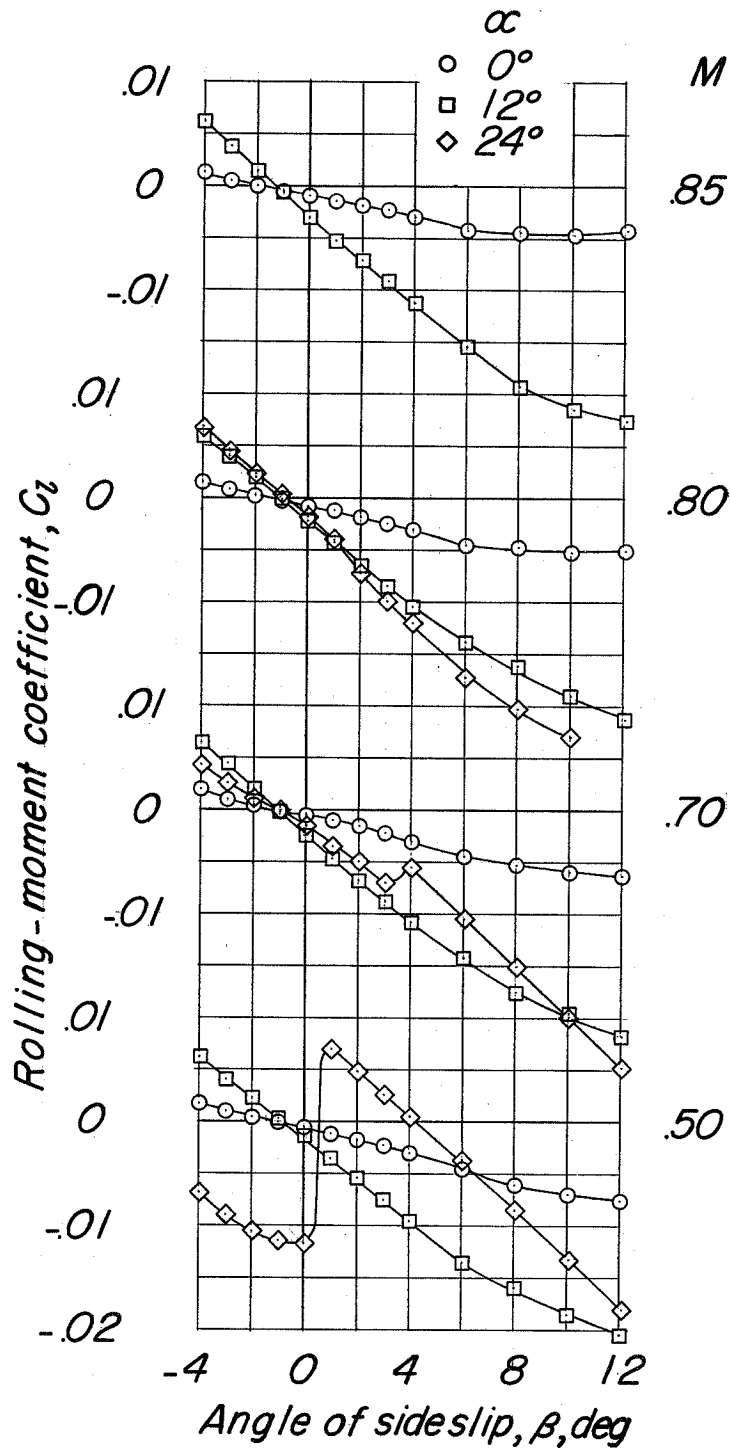
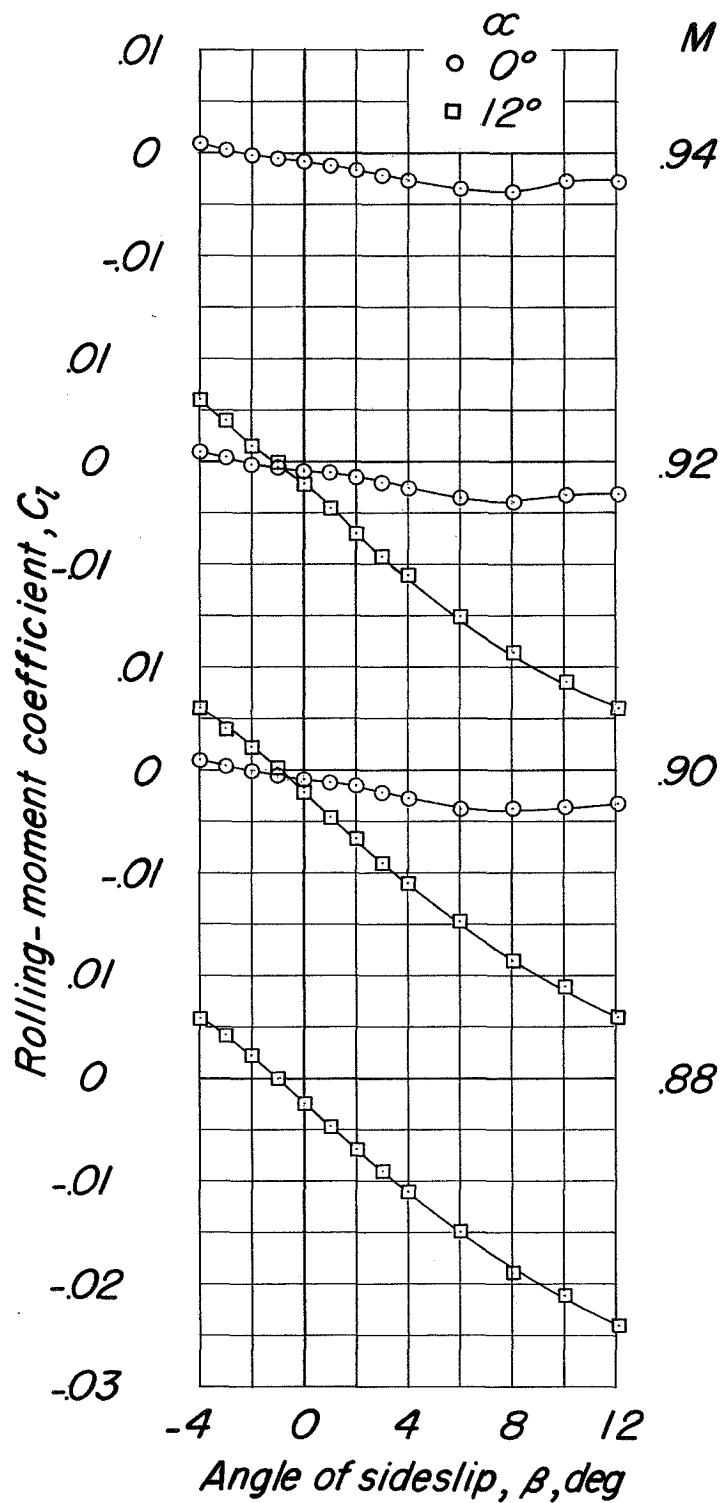
(a)  $C_l$  against  $\beta$ .

Figure 18.- Variation of lateral coefficients with angle of sideslip for configuration BCW<sub>F1</sub> V,  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ .



(a) Concluded.

Figure 18.- Continued.

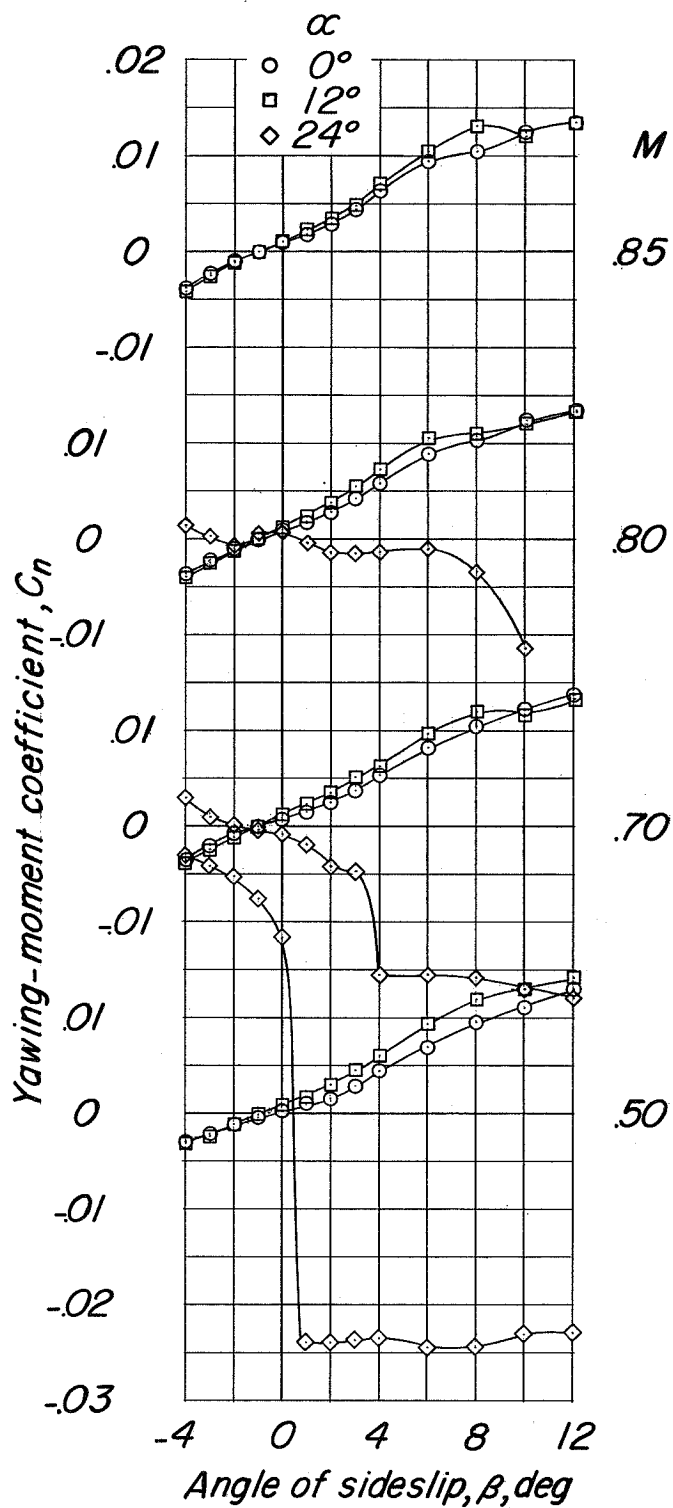
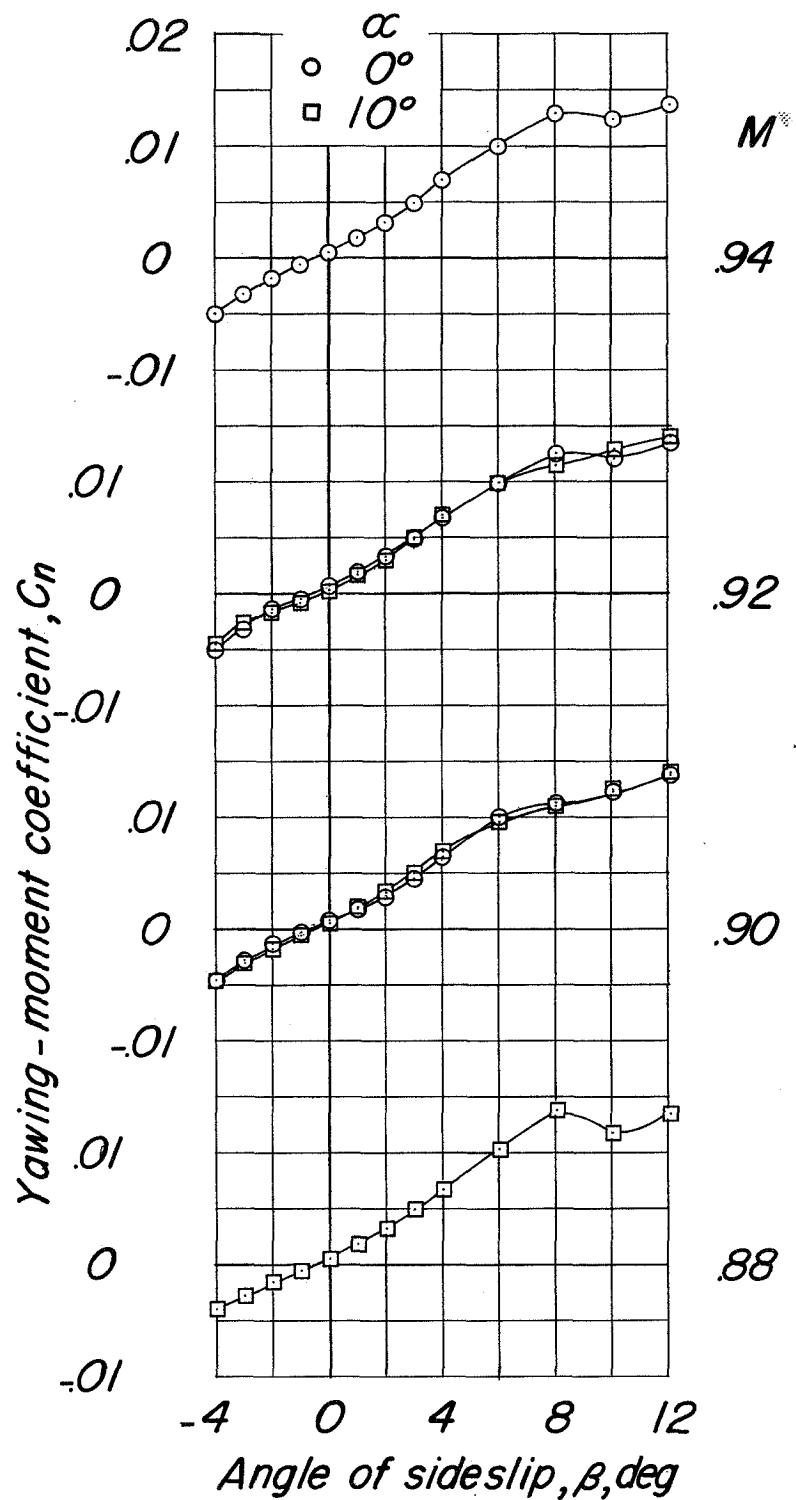
(b)  $C_n$  against  $\beta$ .

Figure 18.- Continued.



(b) Concluded.

Figure 18.- Continued.

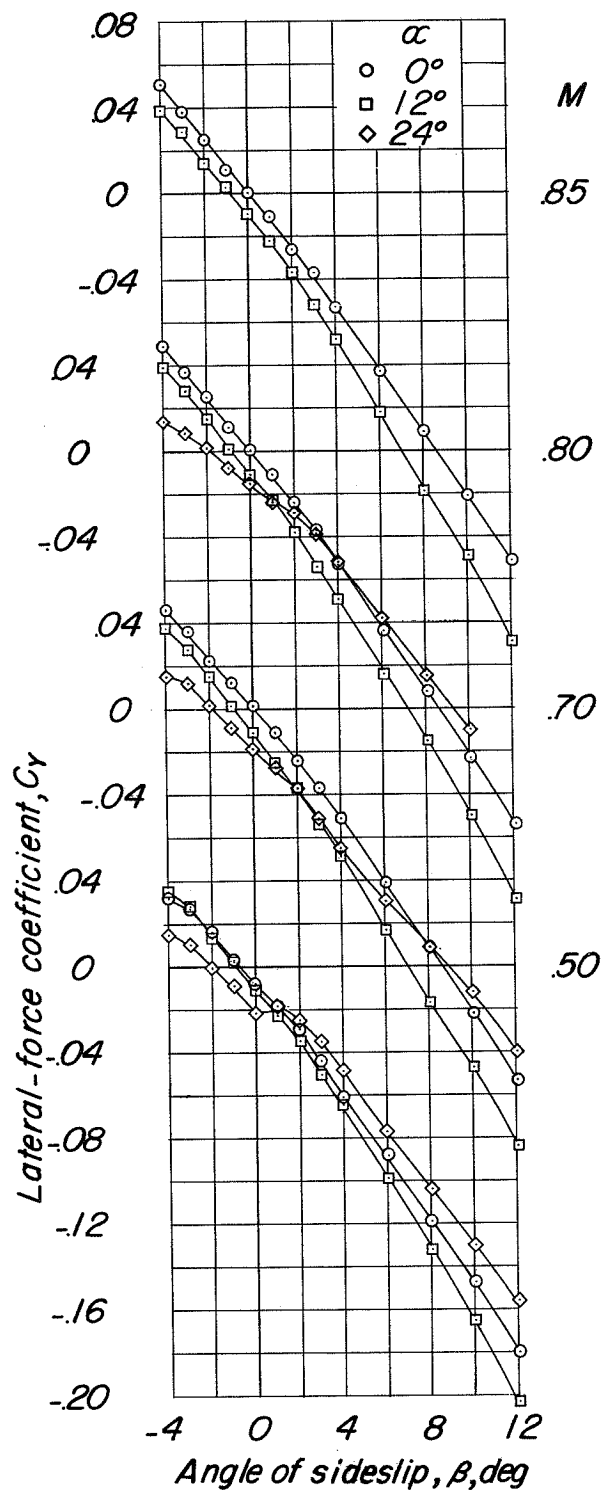
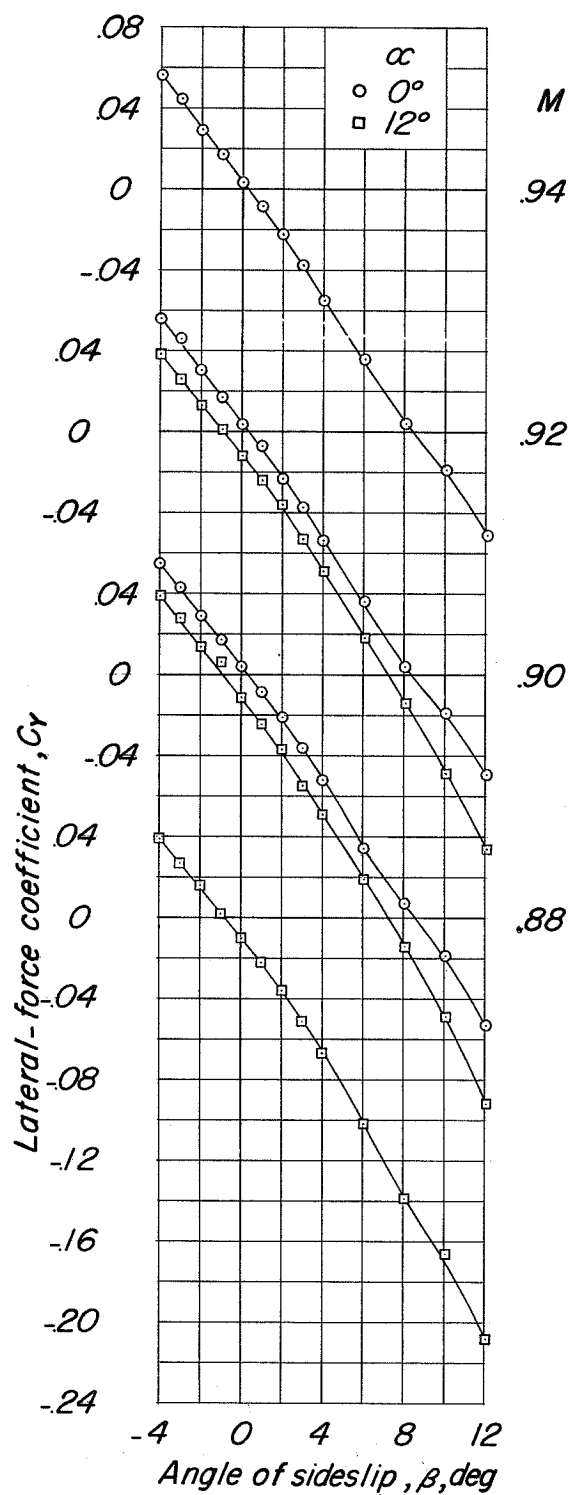
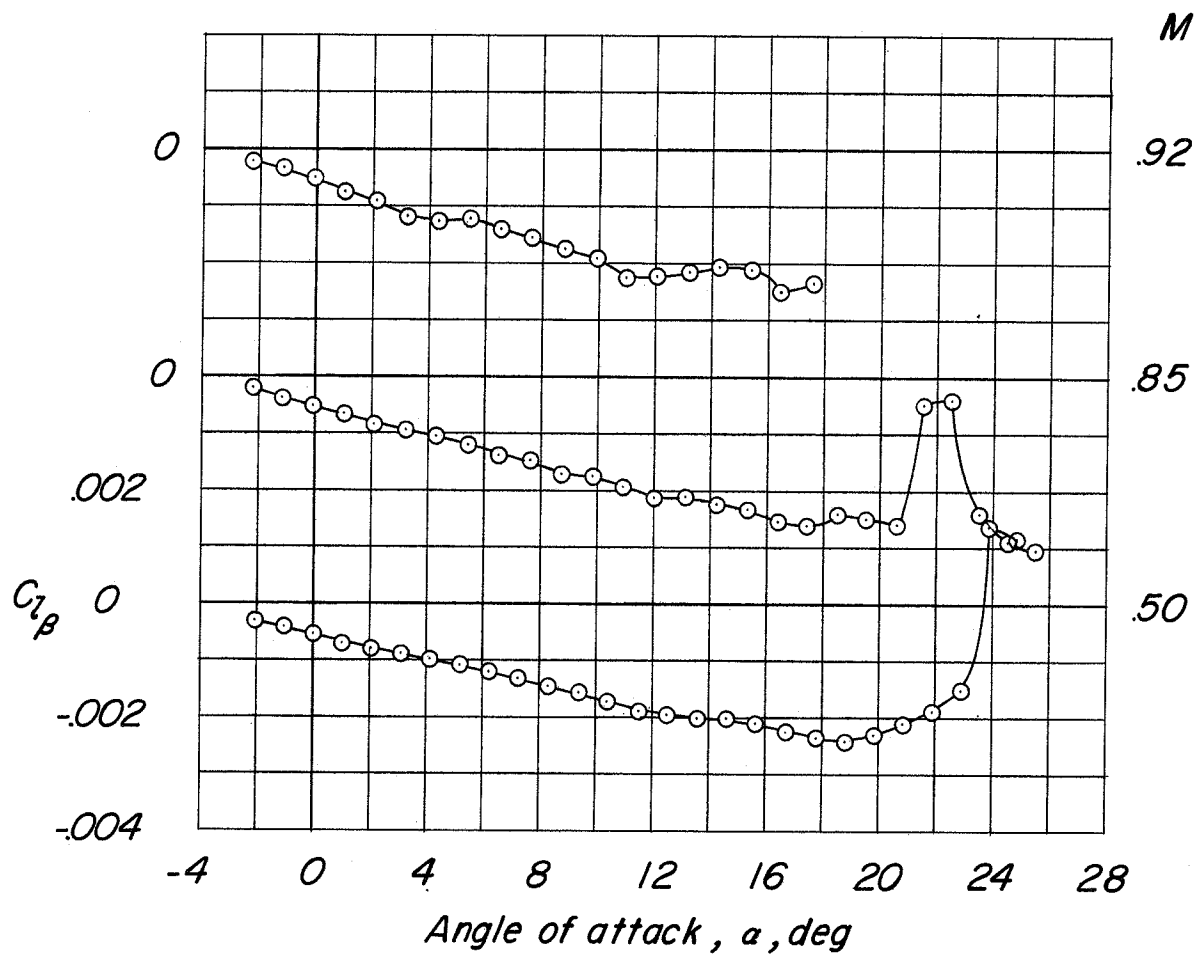
(c)  $C_Y$  against  $\beta$ .

Figure 18.- Continued.



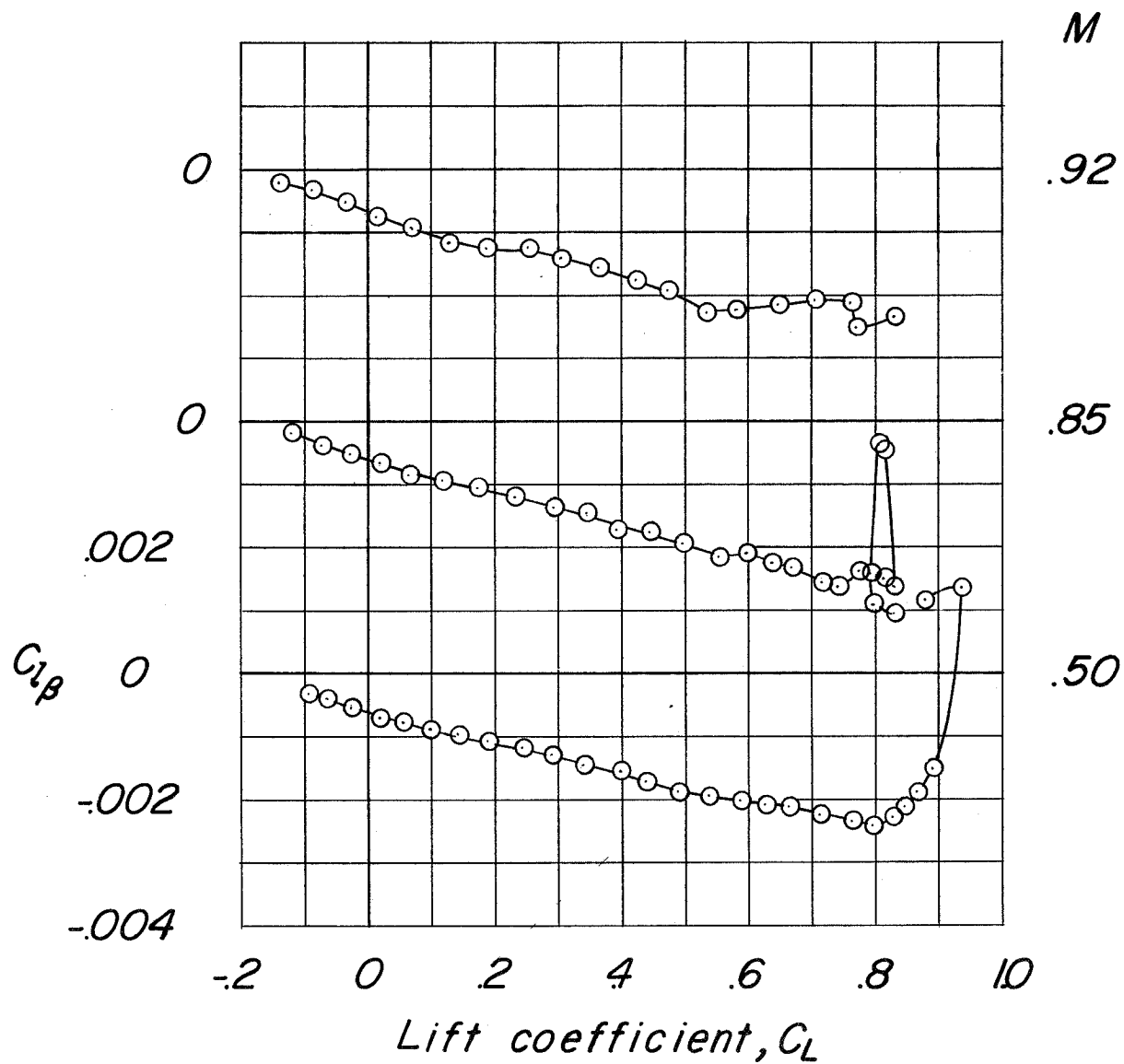
(c) Concluded.

Figure 18.- Concluded.



(a)  $C_{l_{\beta}}$  against  $\alpha$ .

Figure 19.- Variation of lateral-stability parameters with angle of attack for configuration  $BCW_{F1} V$ ,  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ . (Lateral-stability parameters evaluated from angle-of-attack tests at  $\beta = \pm 4^\circ$ .)



(b)  $C_{l_\beta}$  against  $C_L$ .

Figure 19.- Continued.

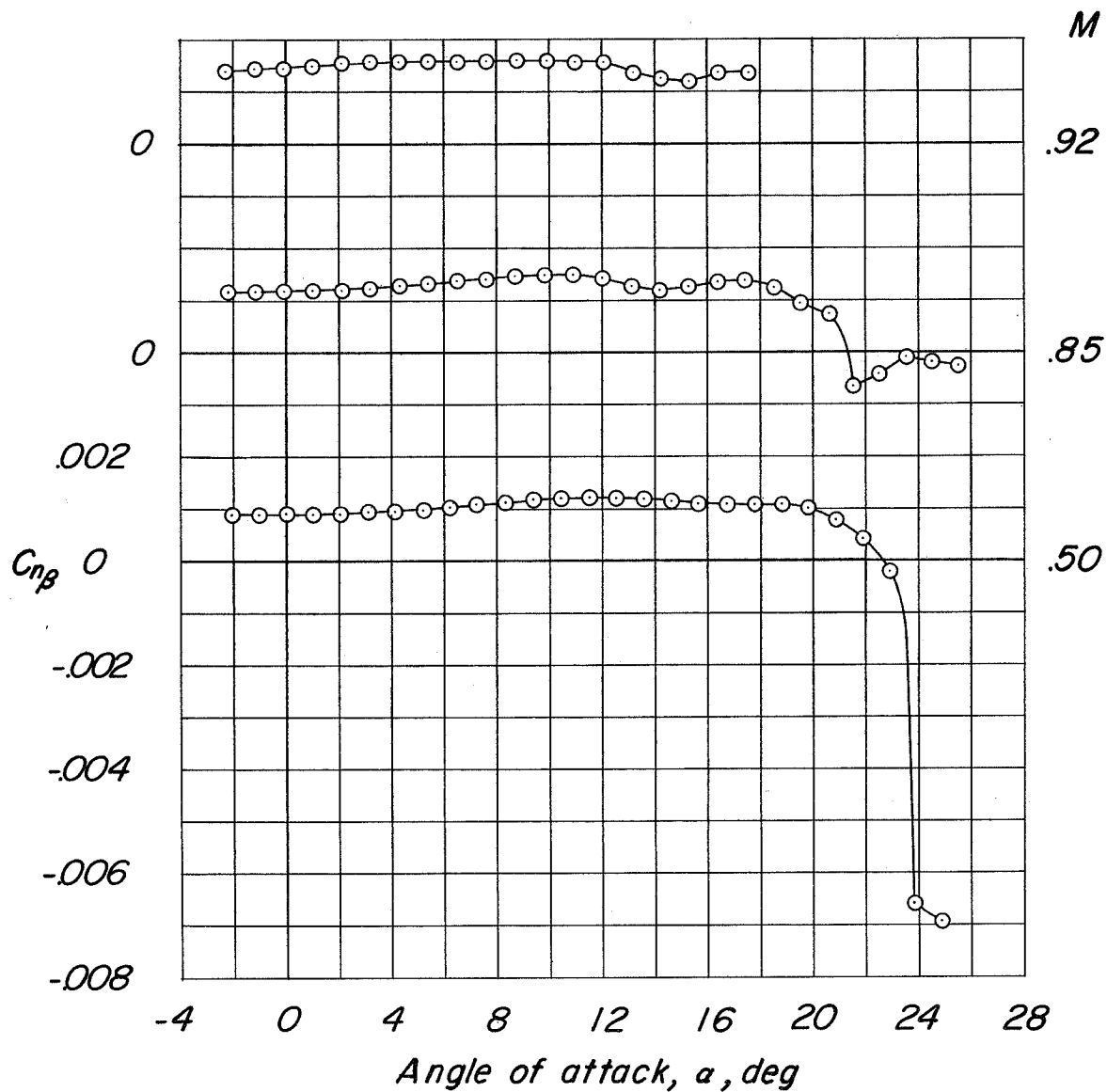
(c)  $C_{n\beta}$  against  $\alpha$ .

Figure 19.- Continued.

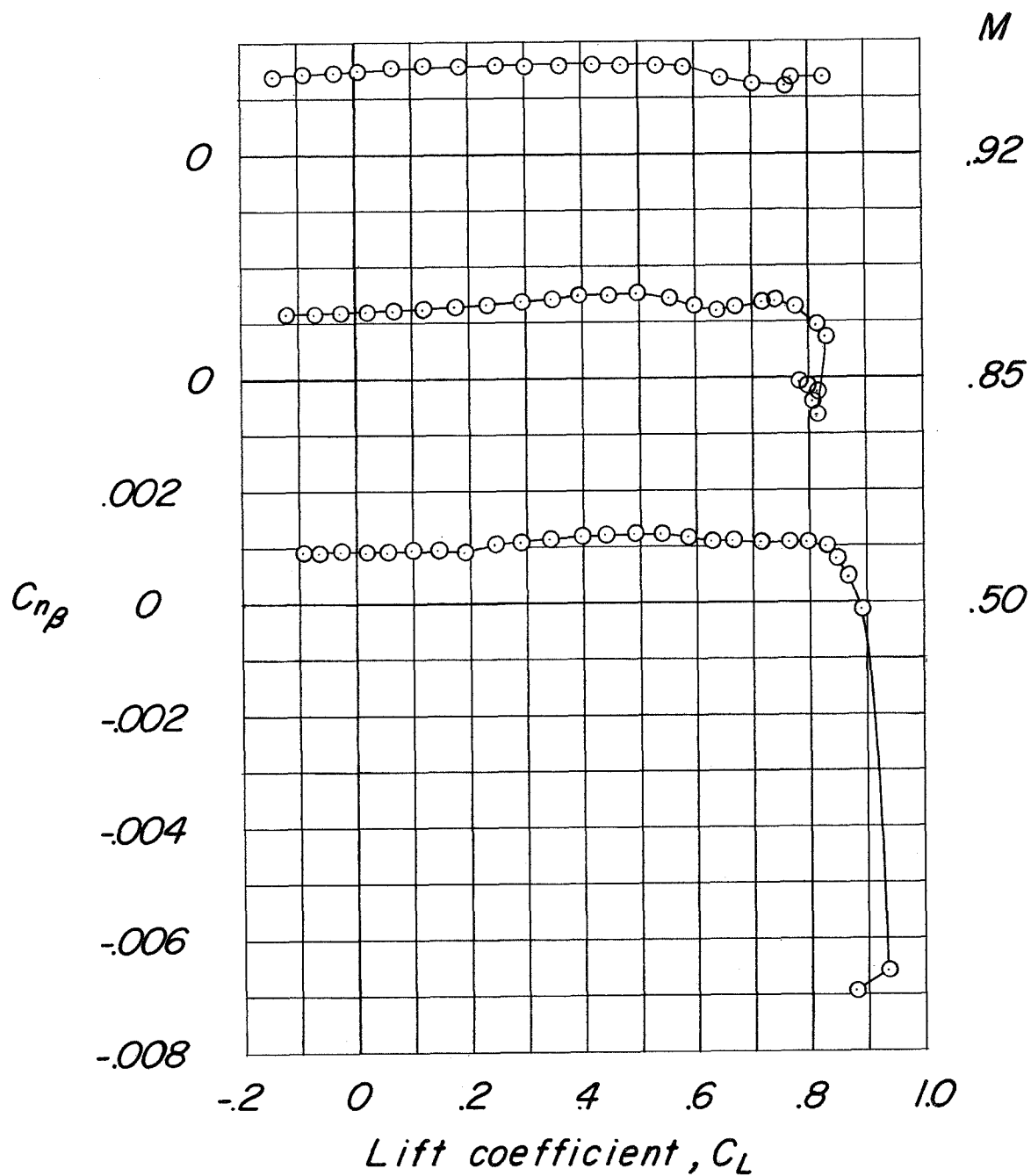
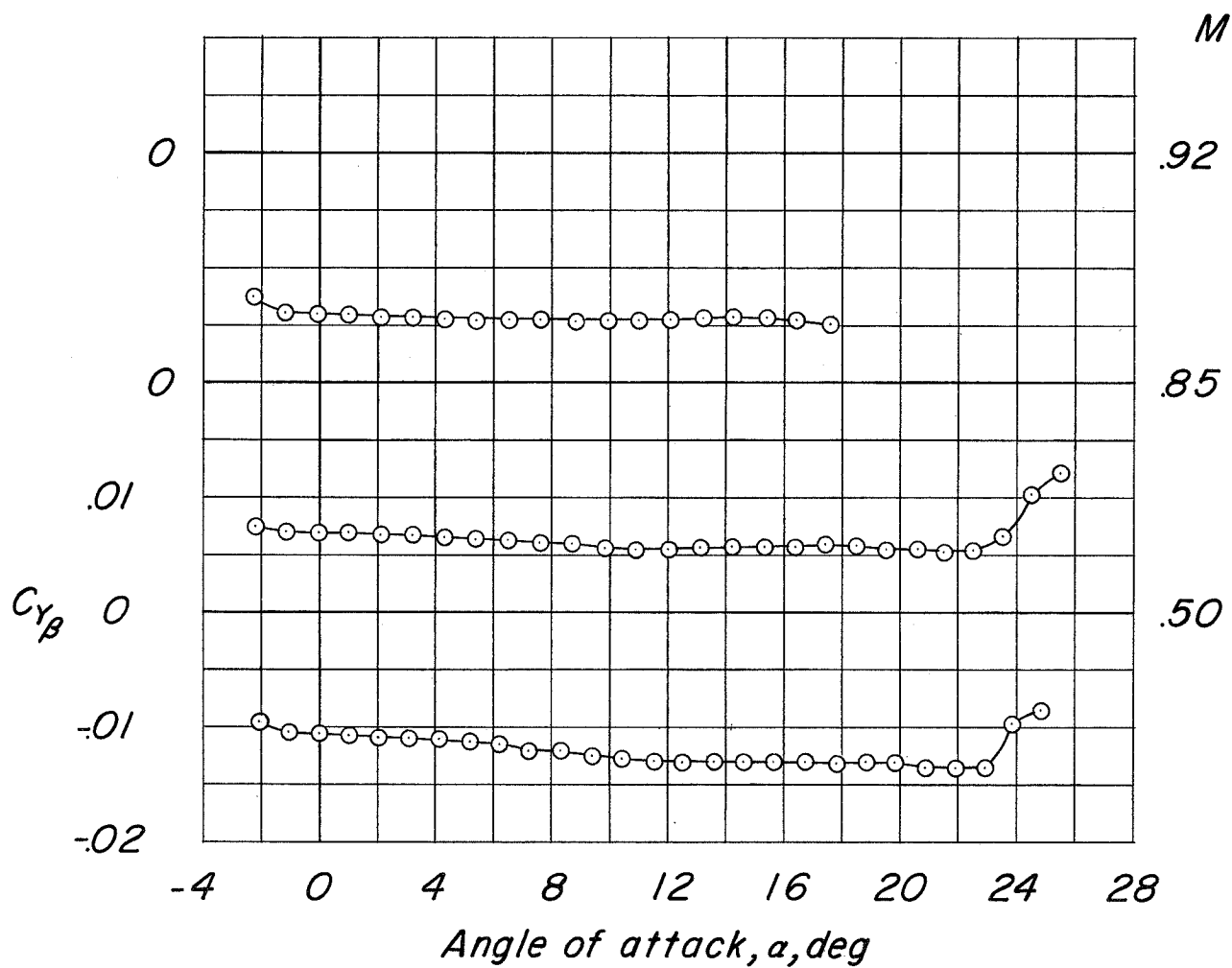
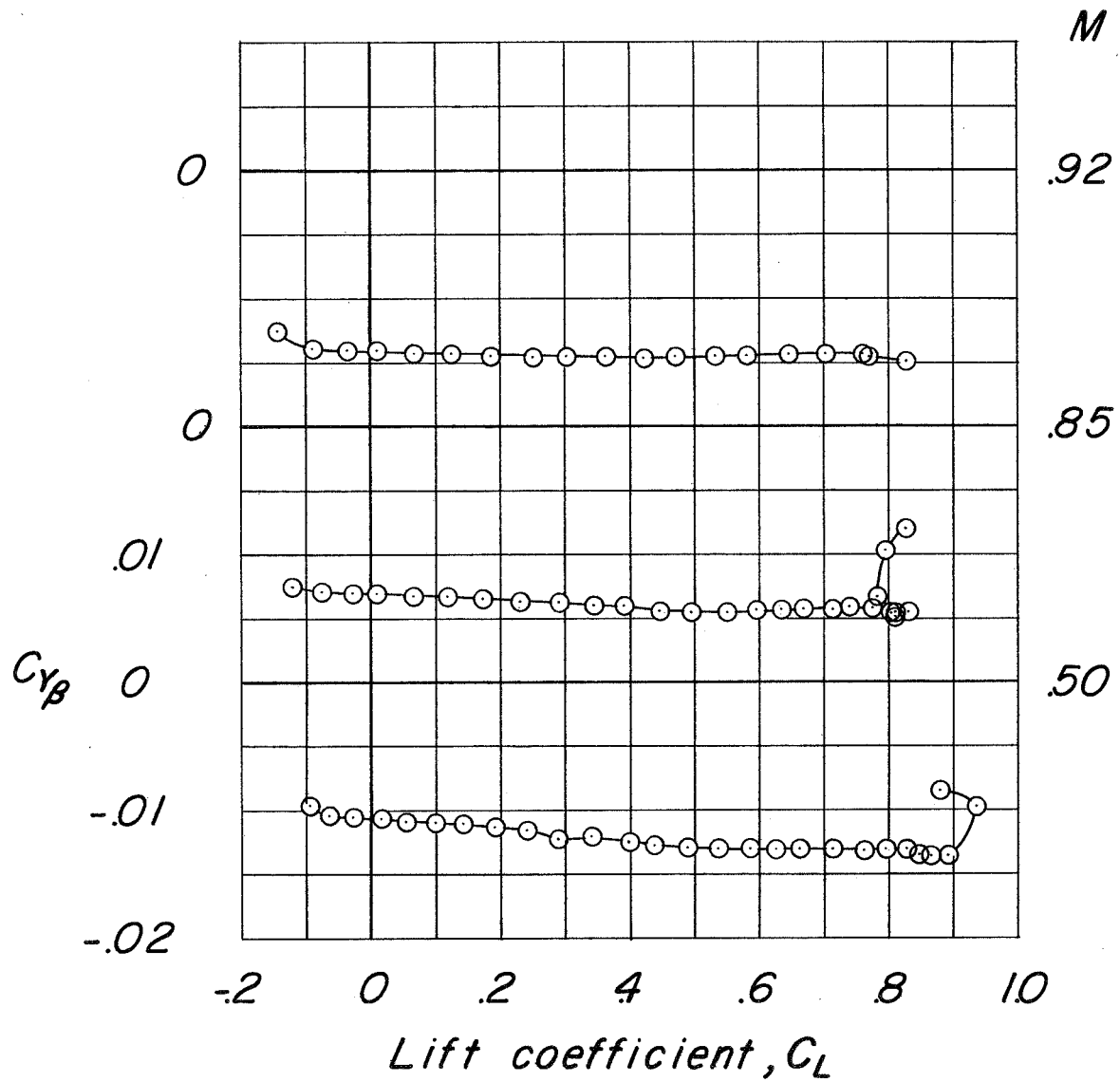
(d)  $C_{n\beta}$  against  $C_L$ .

Figure 19.- Continued.



(e)  $C_{Y_\beta}$  against  $\alpha$ .

Figure 19.- Continued.



(f)  $C_{Y_\beta}$  against  $C_L$ .

Figure 19.- Concluded.

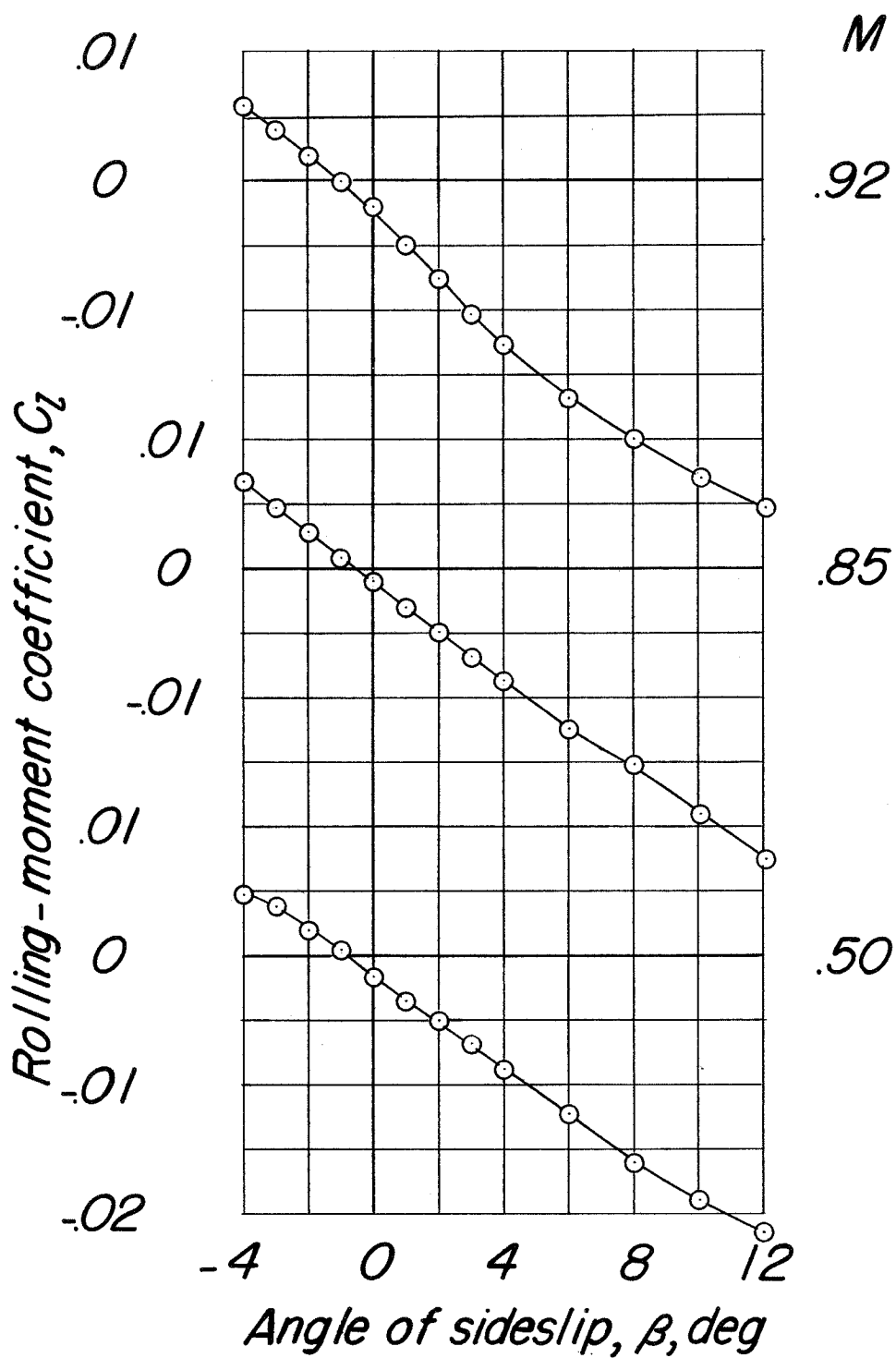
(a)  $C_l$  against  $\beta$ .

Figure 20.- Variation of lateral coefficients with angle of sideslip for configuration  $BCW_{F1+RPV}$ ,  $\delta_e = 0^\circ$ ,  $\delta_r = 0^\circ$ .  $\alpha = 12^\circ$ .

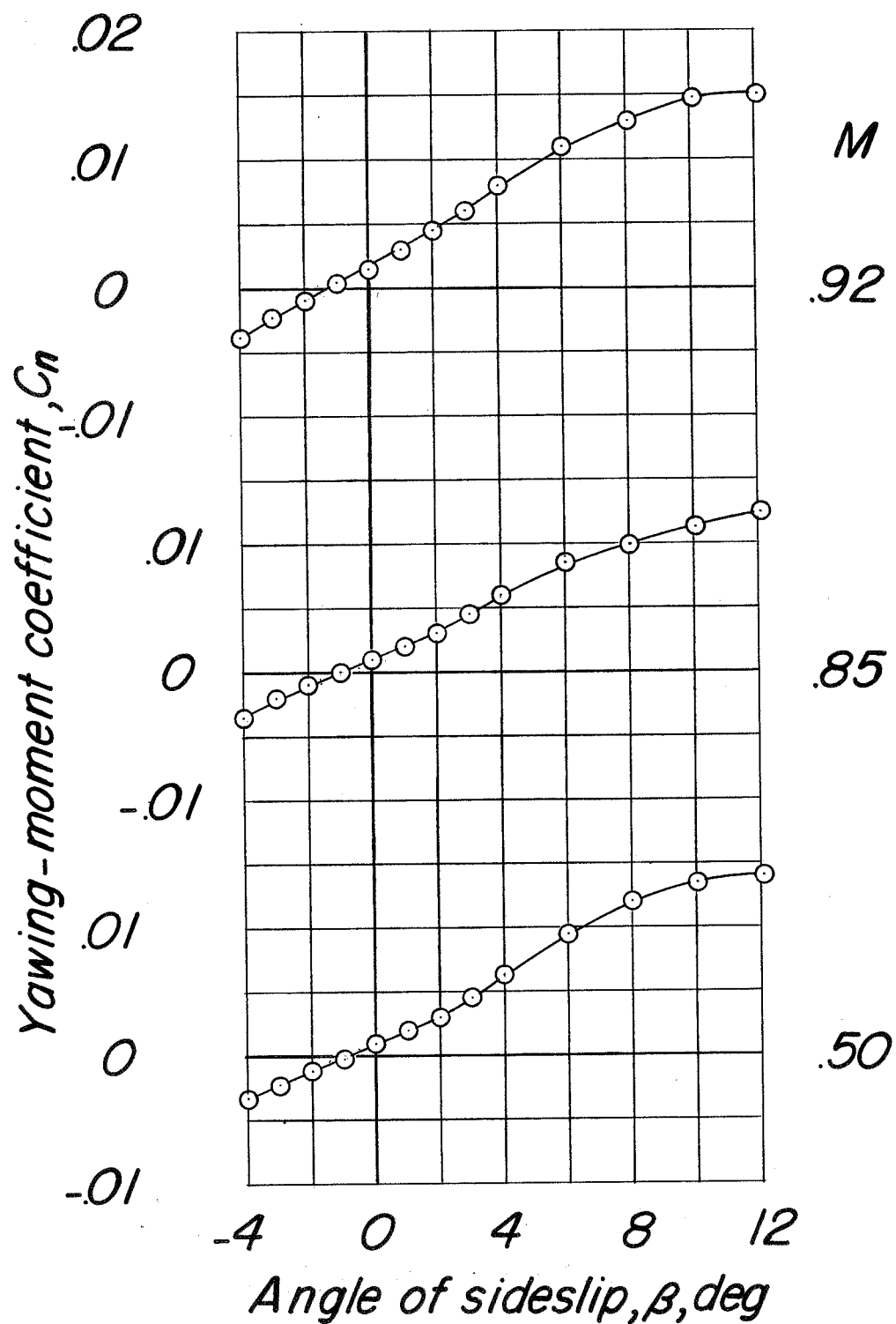
(b)  $C_n$  against  $\beta$ .

Figure 20.- Continued.

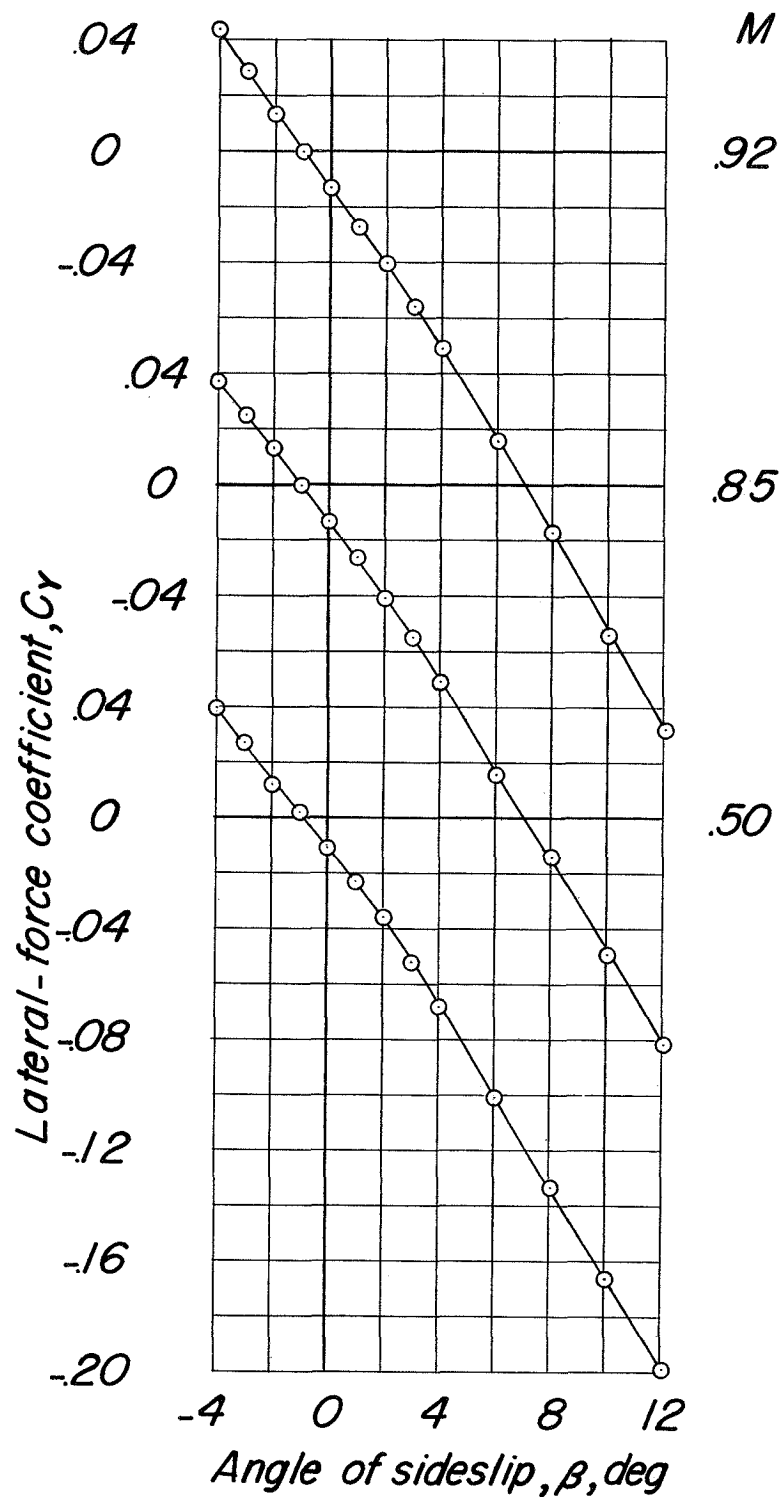
(c)  $C_Y$  against  $\beta$ .

Figure 20.- Concluded.

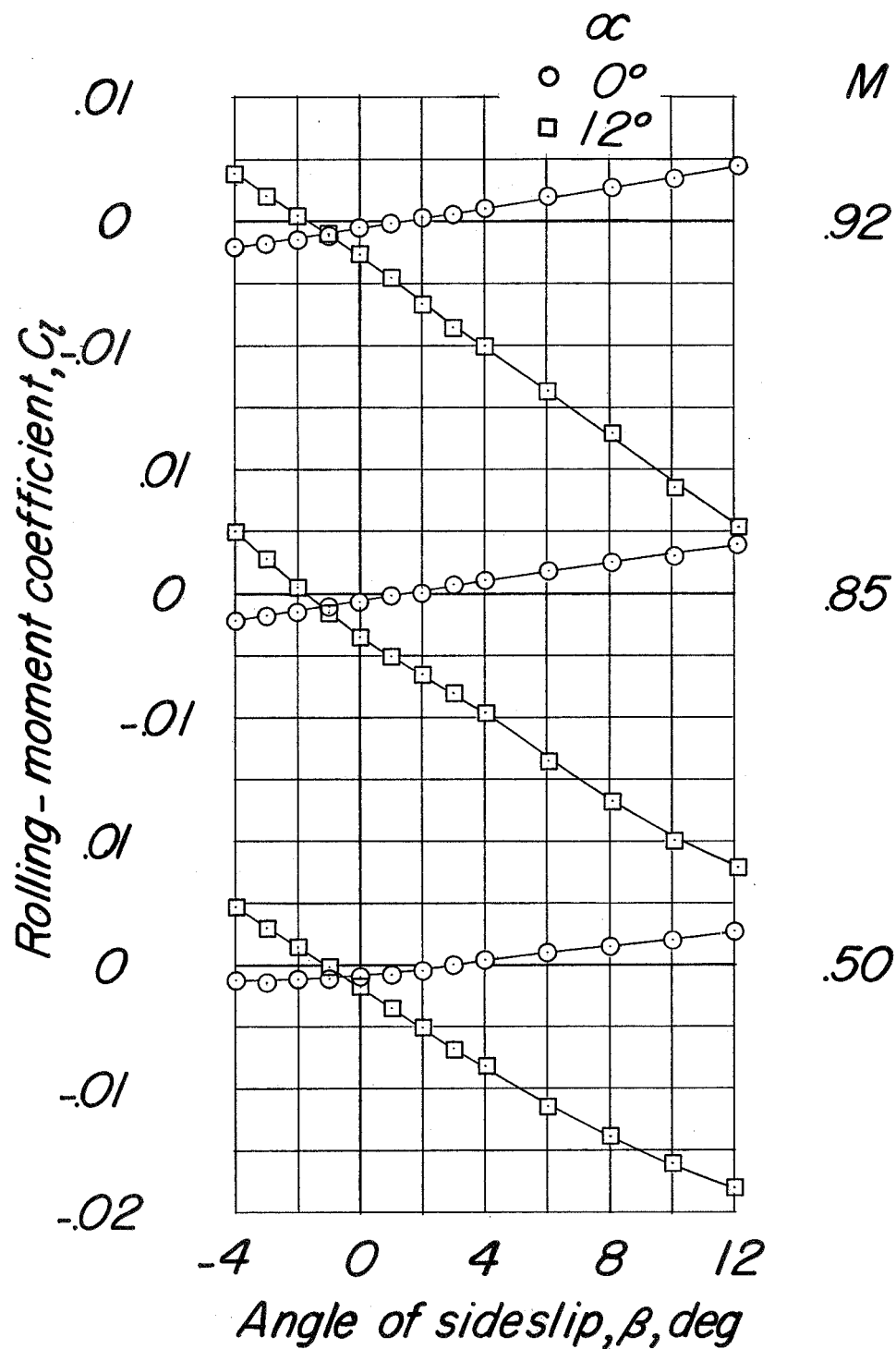
(a)  $C_l$  against  $\beta$ .

Figure 21.- Variation of lateral coefficients with angle of sideslip for configuration BCW<sub>F1</sub>,  $\delta_e = 0^\circ$ .

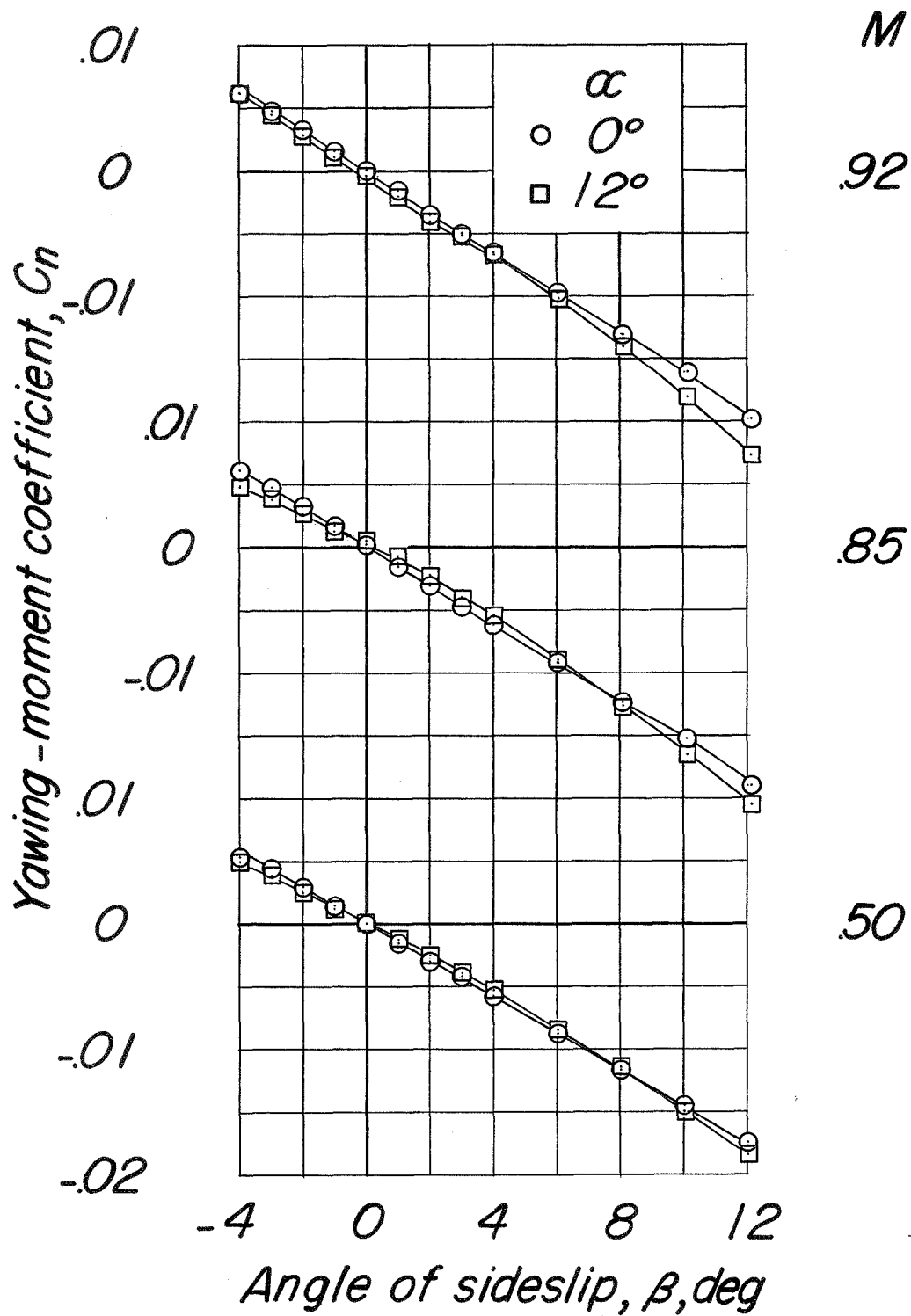
(b)  $C_n$  against  $\beta$ .

Figure 21.- Continued.

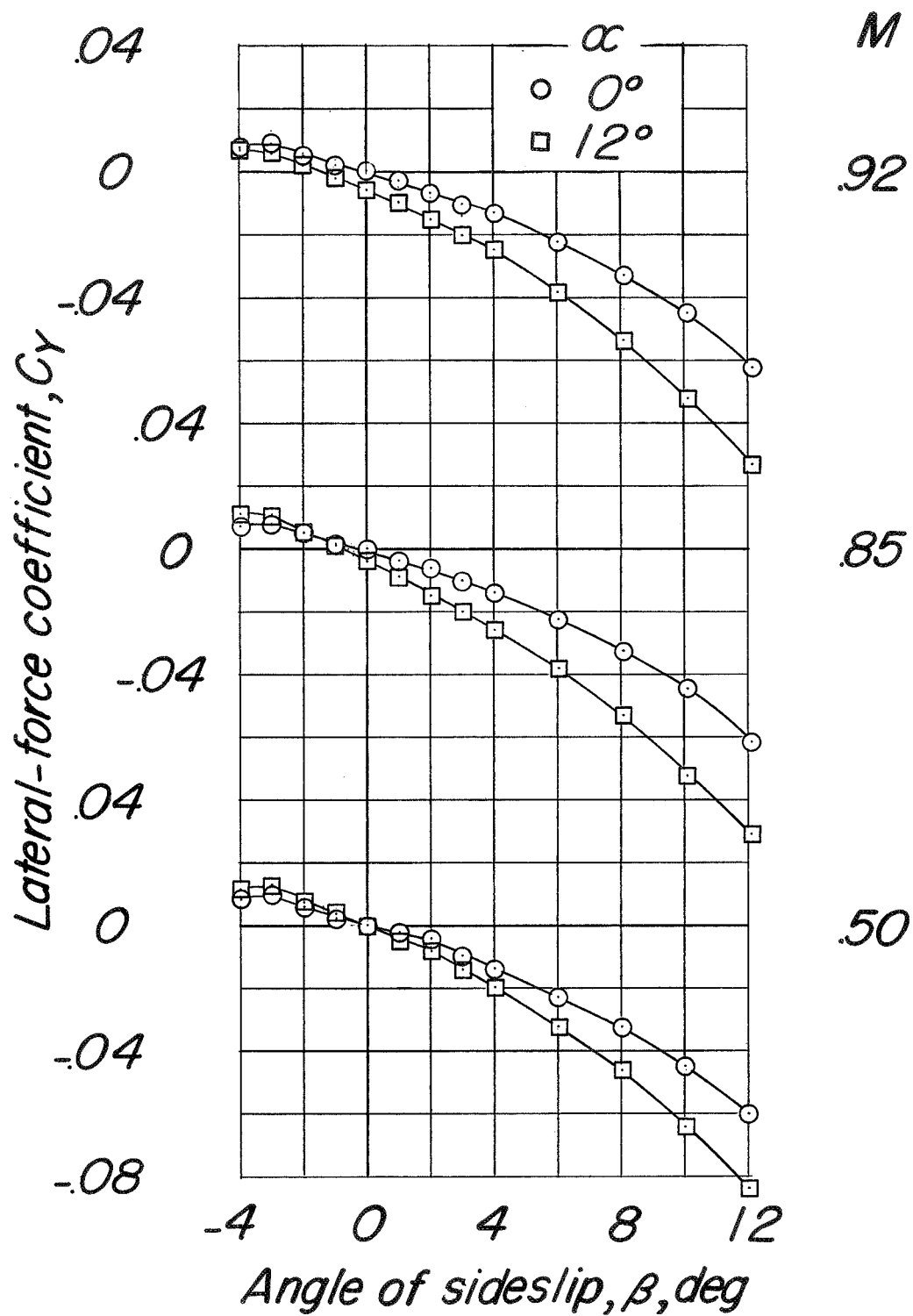
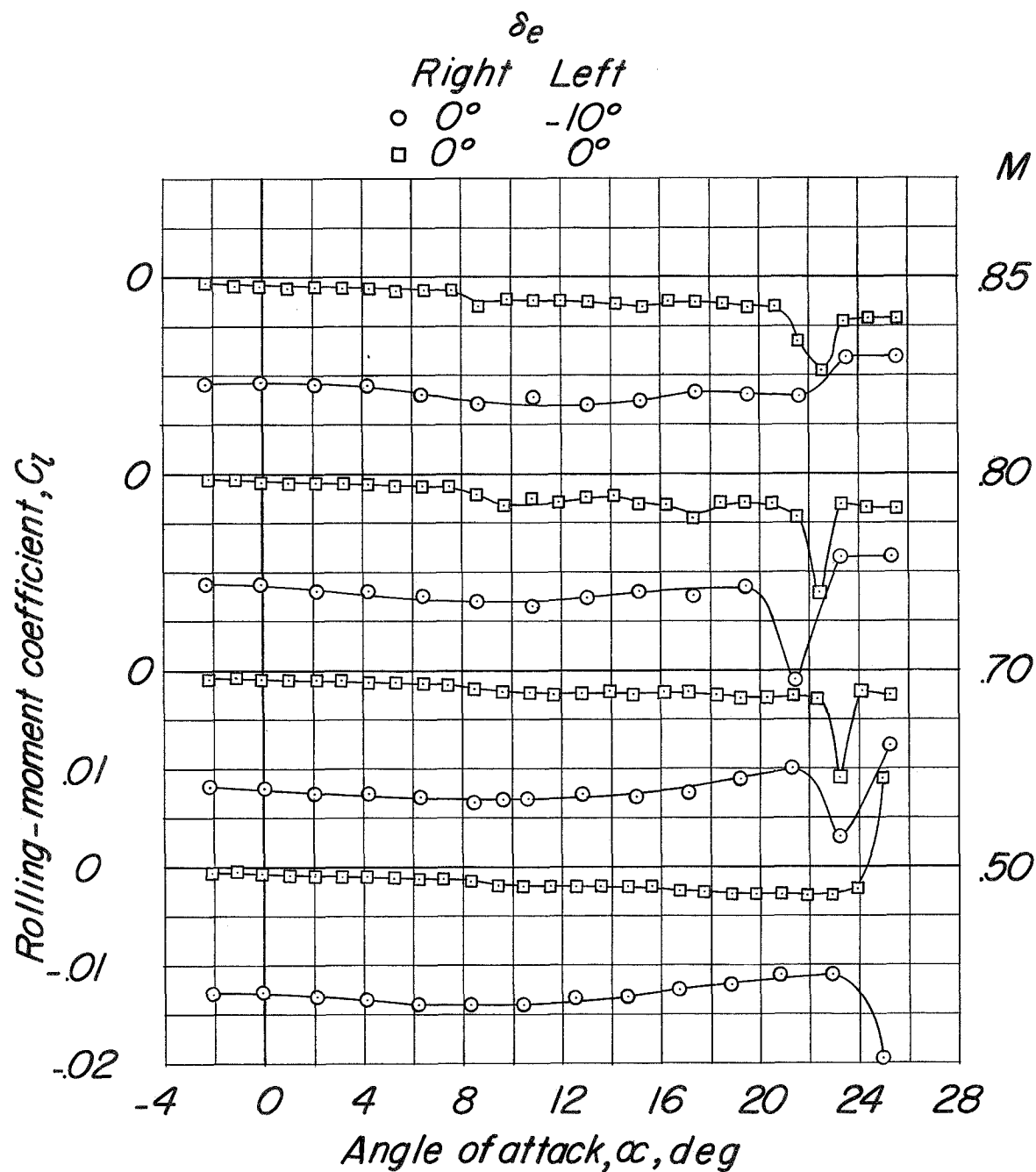
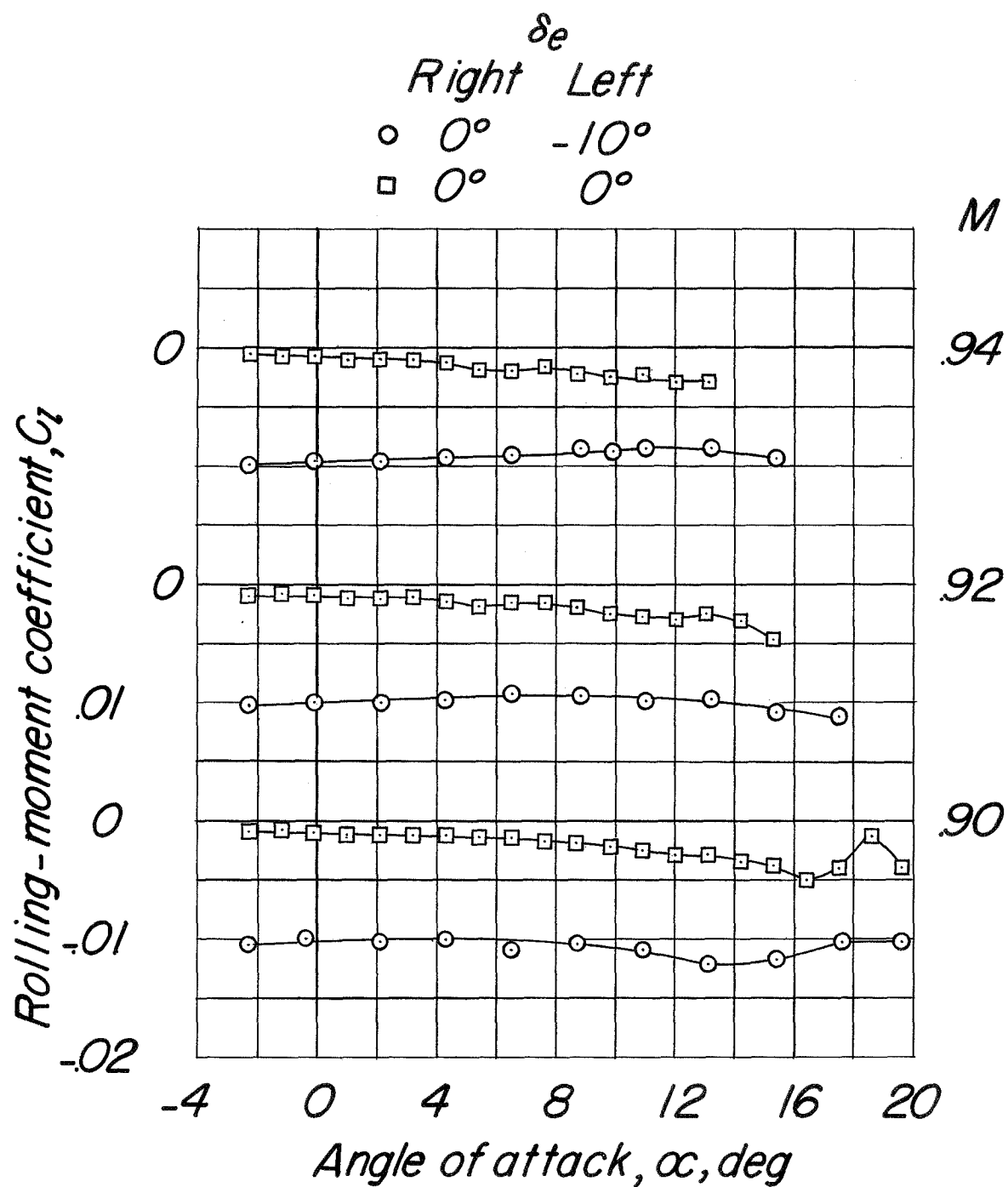
(c)  $C_Y$  against  $\beta$ .

Figure 21.- Concluded.

(a)  $C_l$  against  $\alpha$ .Figure 22.- Aerodynamic characteristics in pitch to determine lateral control effectiveness for configuration BCW<sub>F1</sub>V,  $\delta_r = 0^\circ$ .



(a) Concluded.

Figure 22.- Continued.

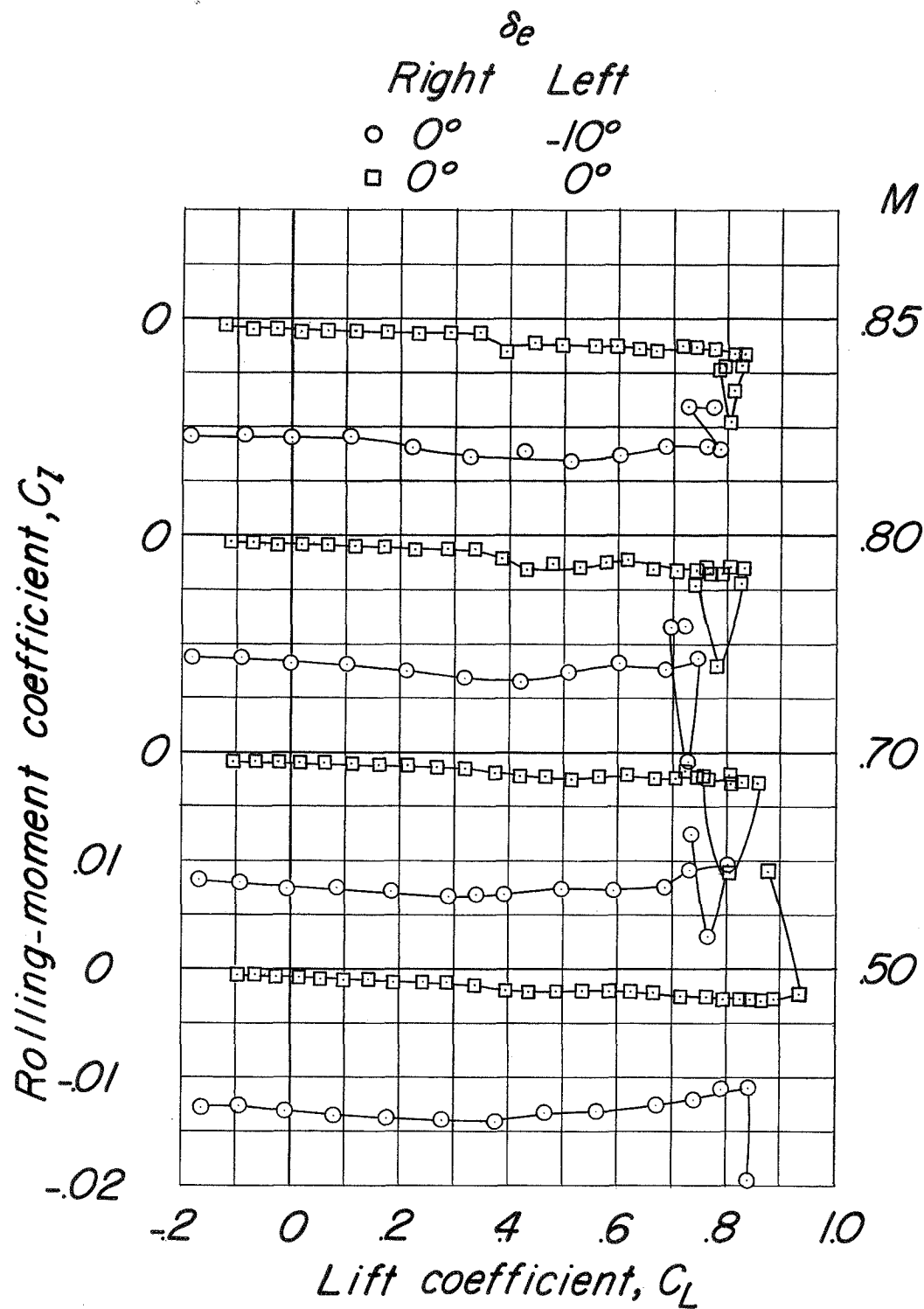
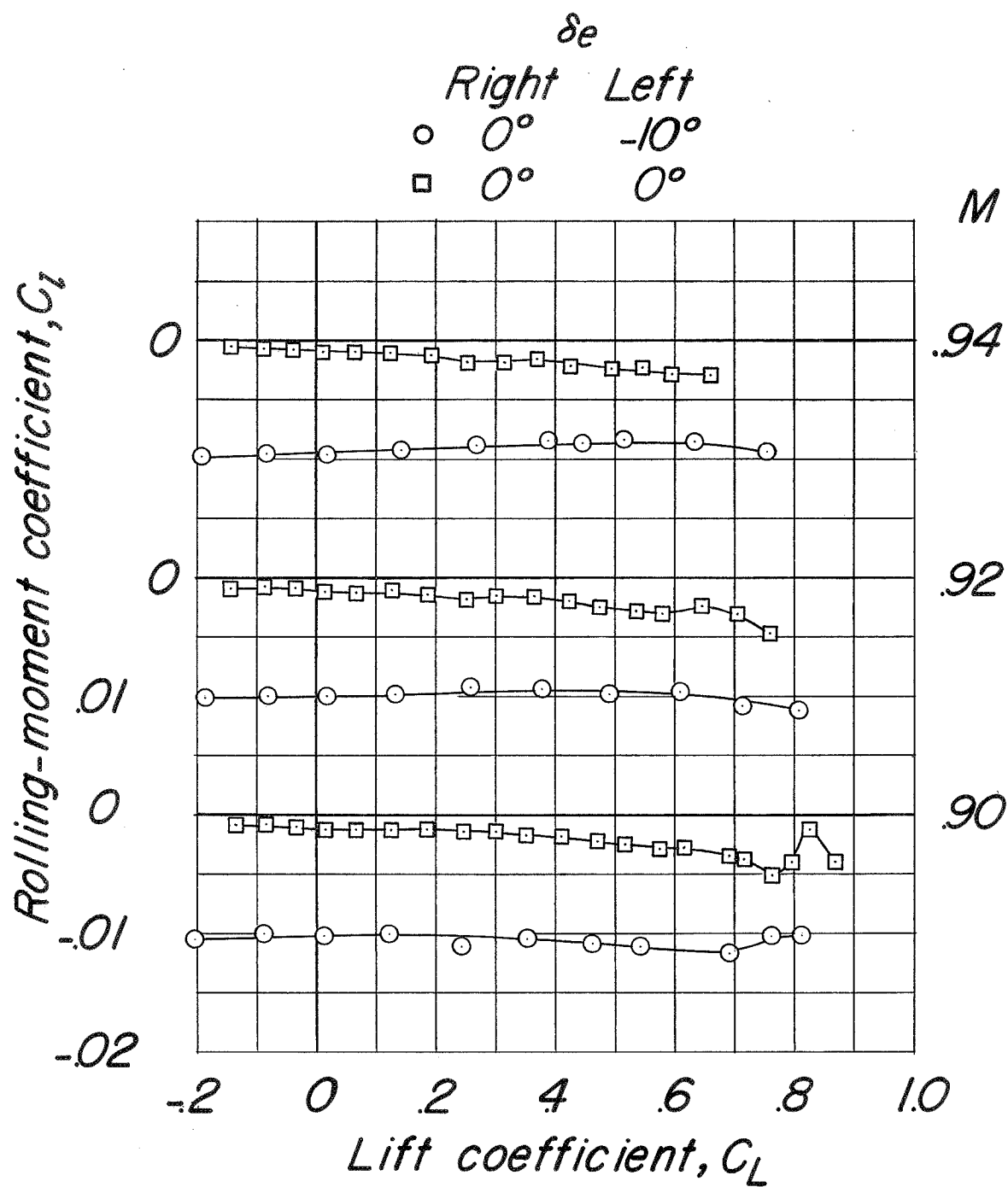
(b)  $C_l$  against  $C_L$ .

Figure 22.- Continued.



(b) Concluded.

Figure 22.- Continued.

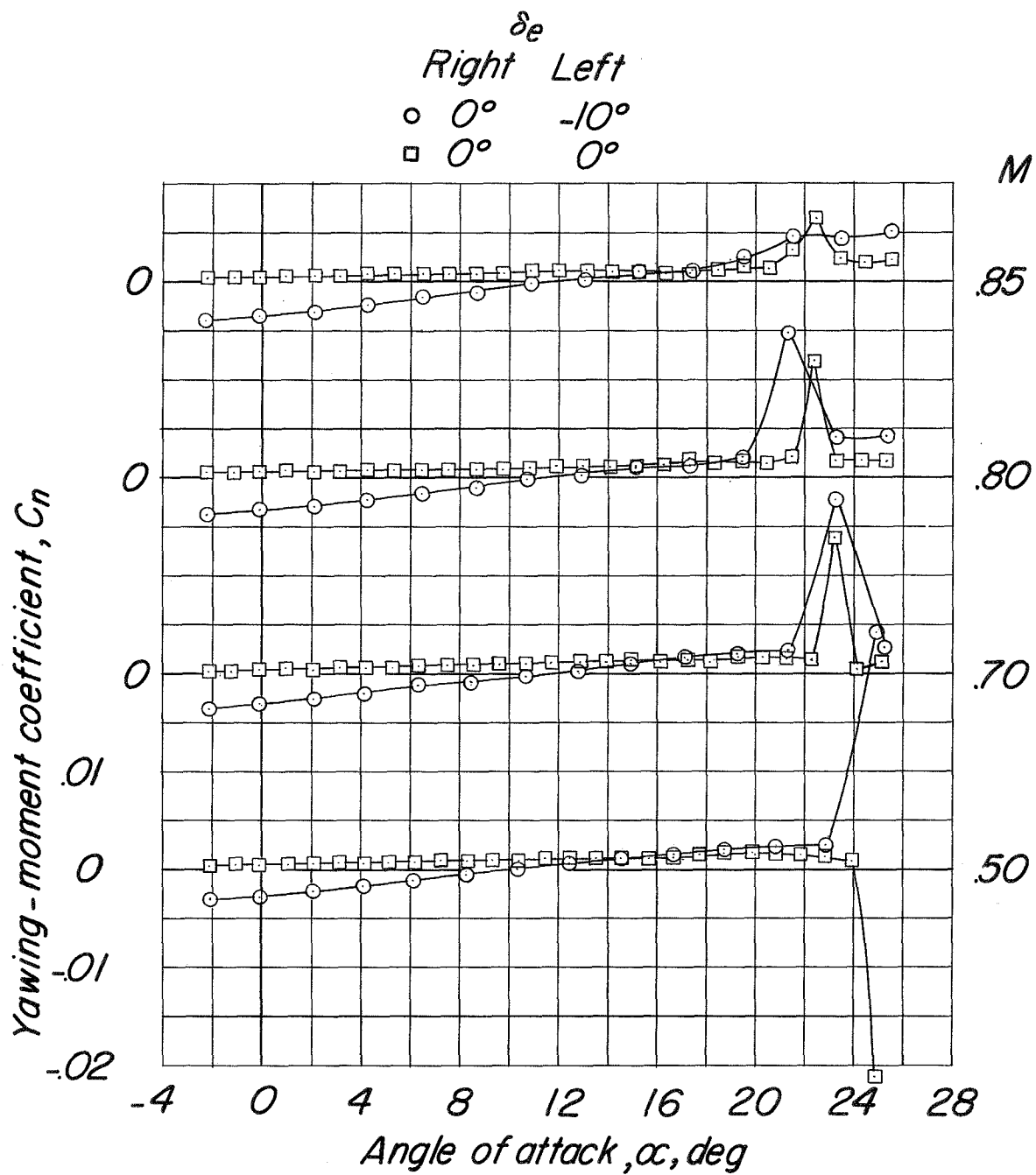
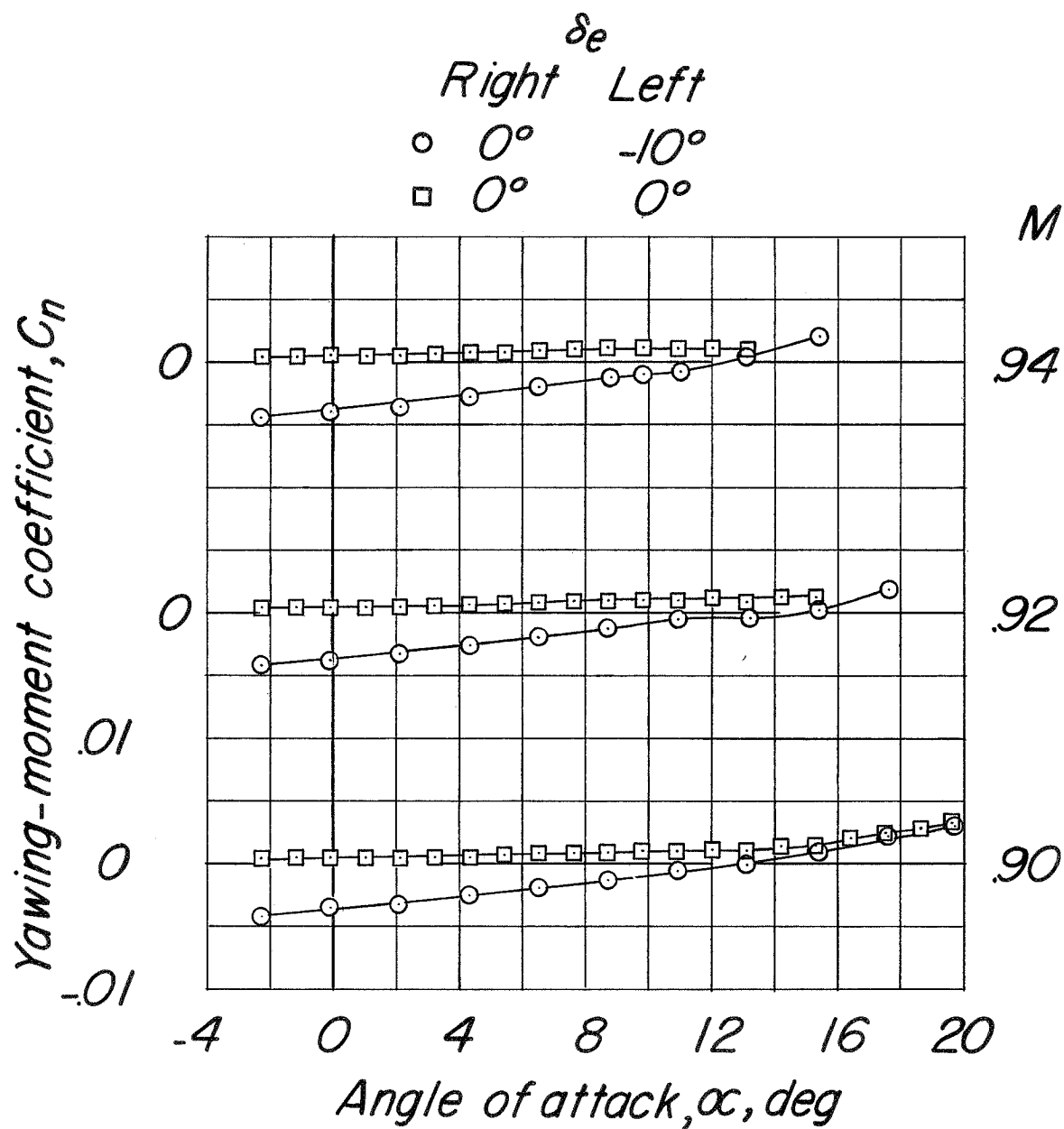
(c)  $C_n$  against  $\alpha$ .

Figure 22.- Continued.



(c) Concluded.

Figure 22.- Continued.

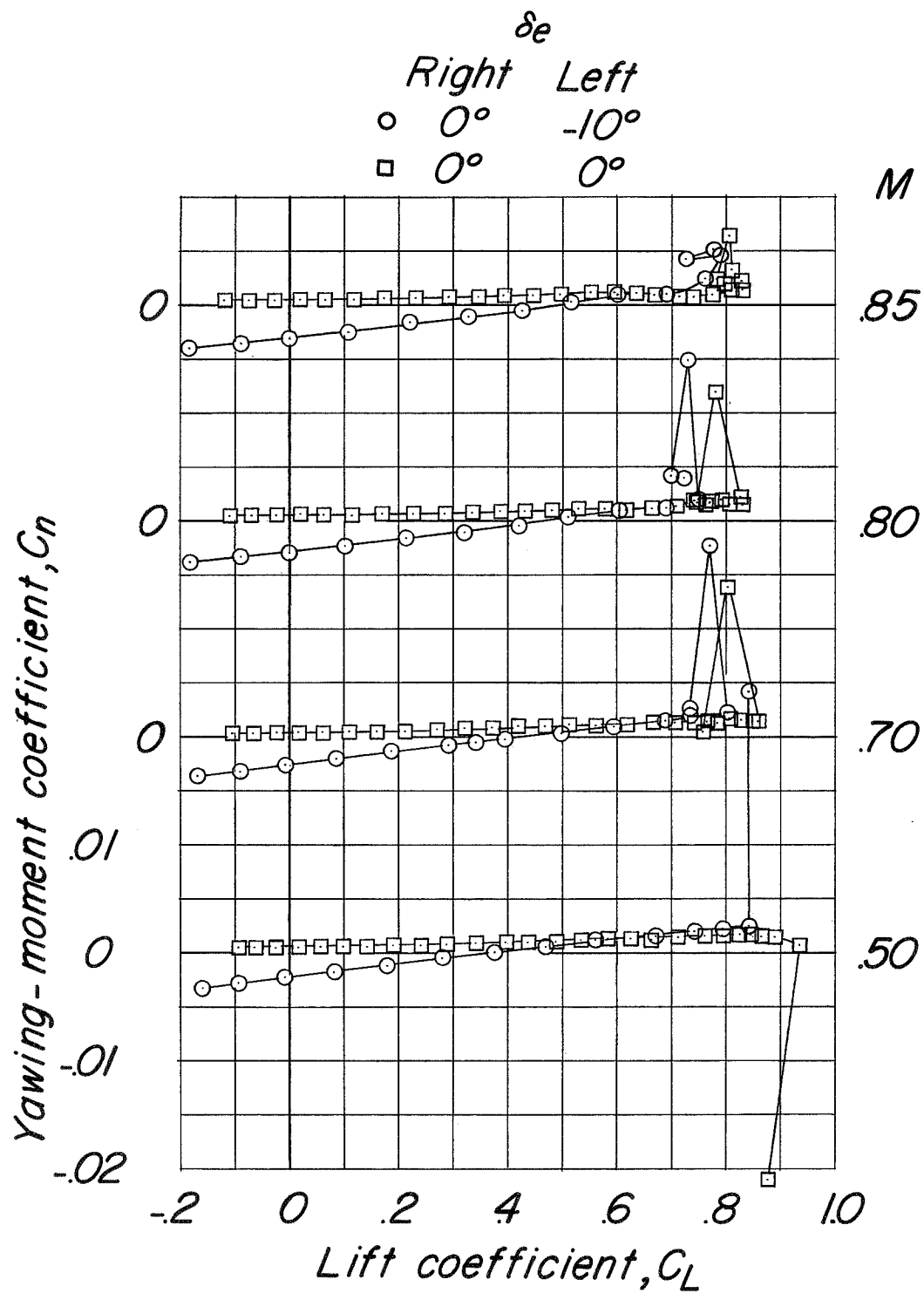
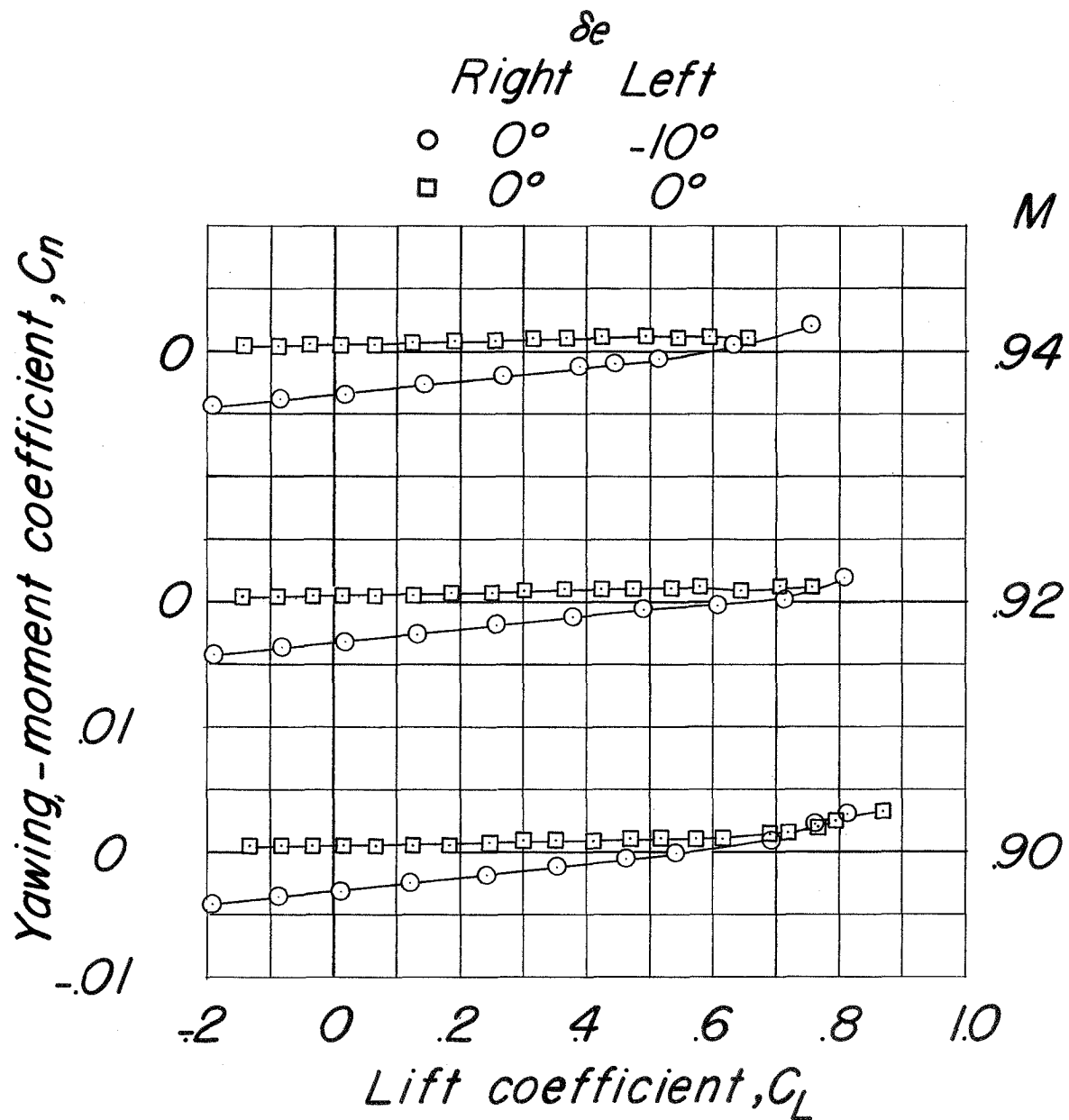
(d)  $C_n$  against  $C_L$ .

Figure 22.- Continued.



(d) Concluded.

Figure 22.- Continued.

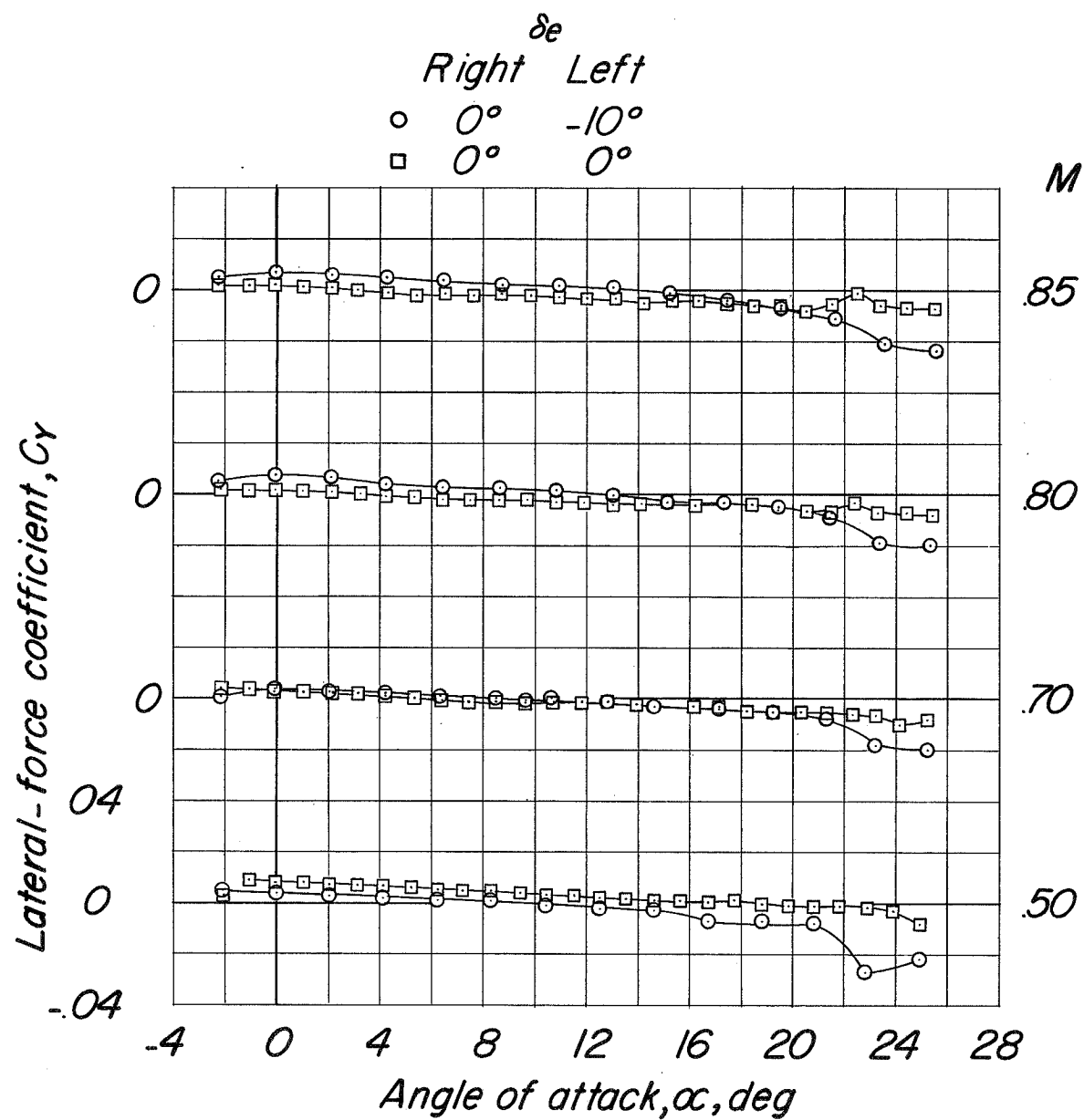
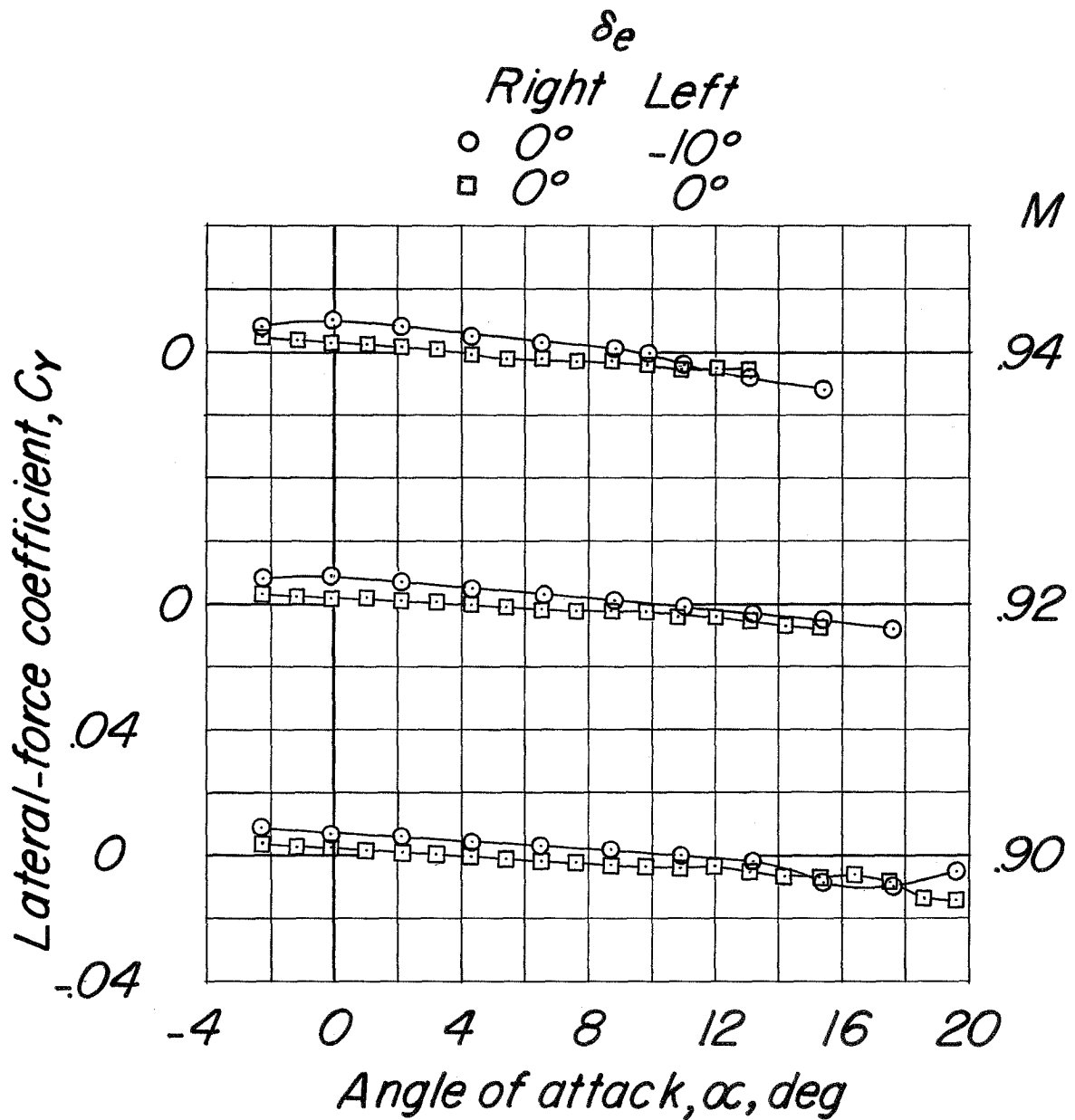
(e)  $C_Y$  against  $\alpha$ .

Figure 22.- Continued.



(e) Concluded.

Figure 22.- Continued.

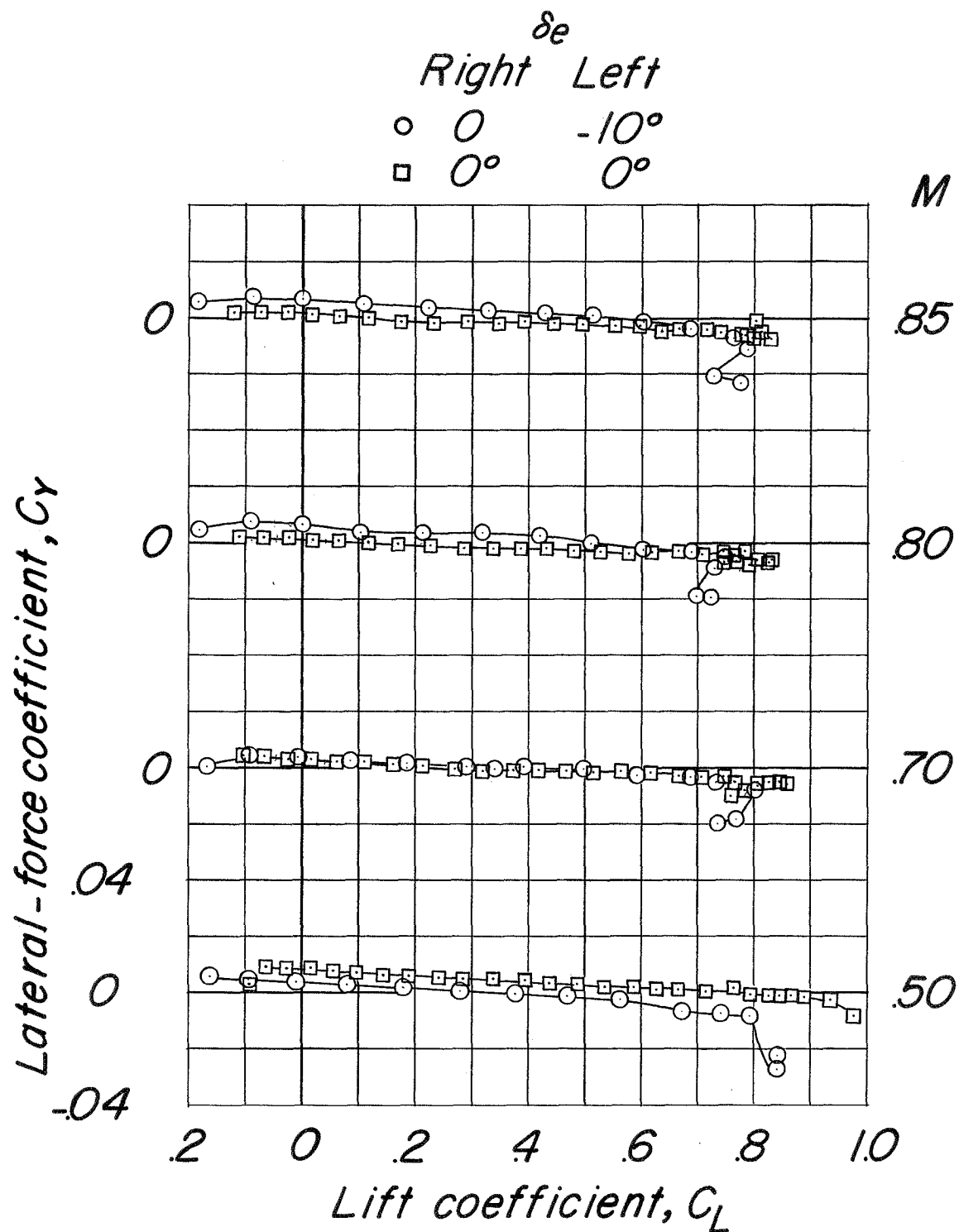
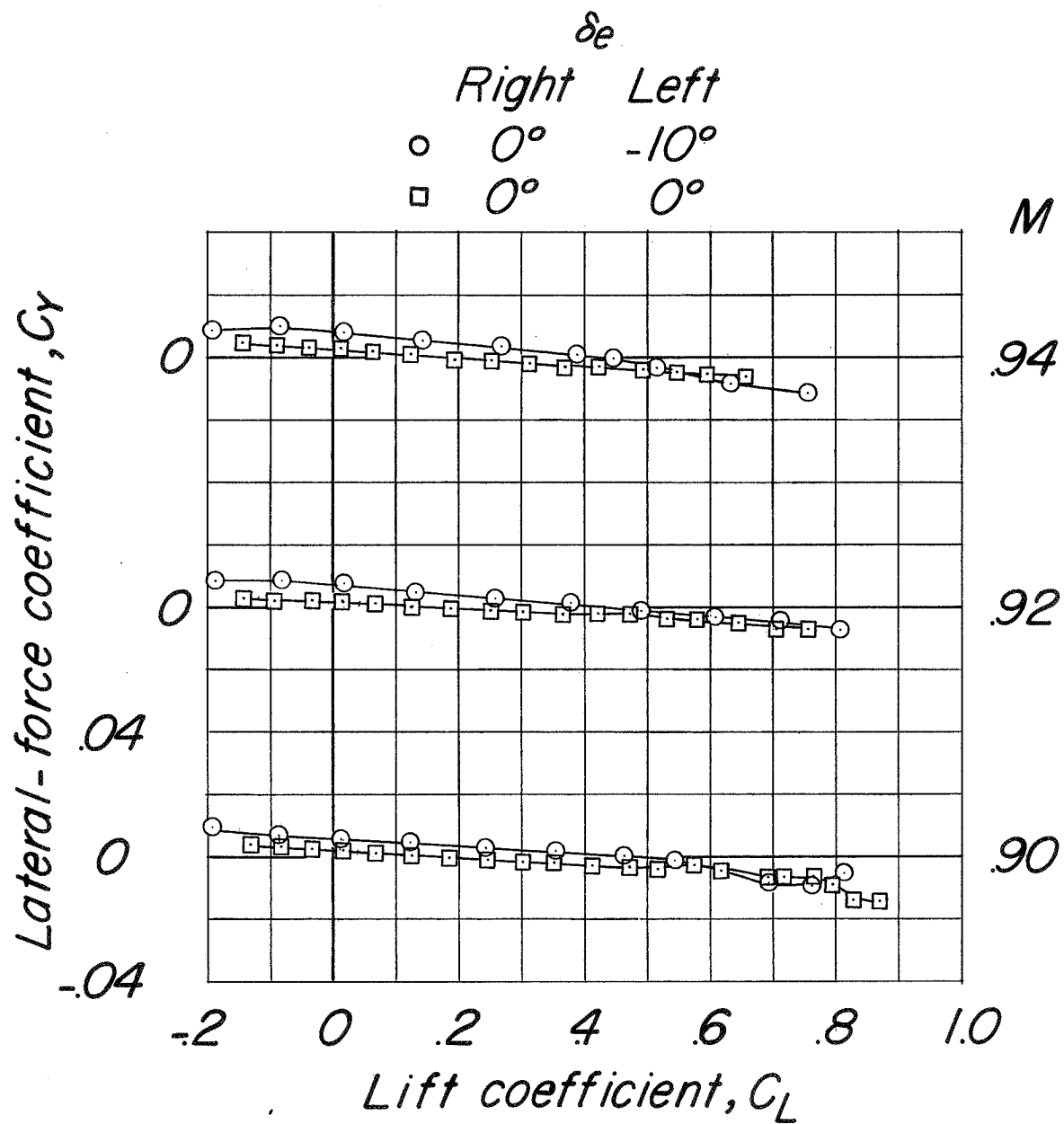
(f)  $C_Y$  against  $C_L$ .

Figure 22.- Continued.



(f) Concluded.

Figure 22.- Concluded.

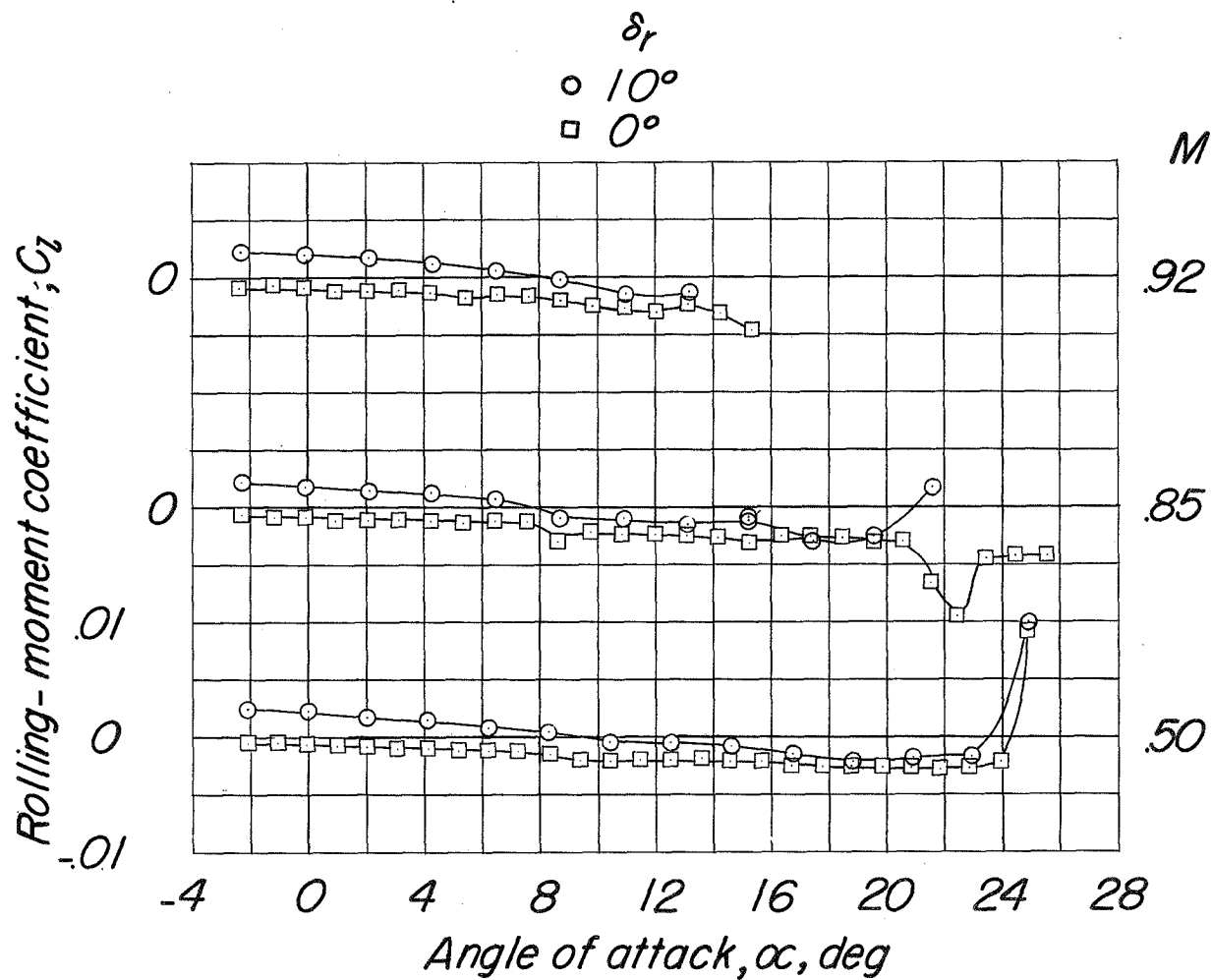
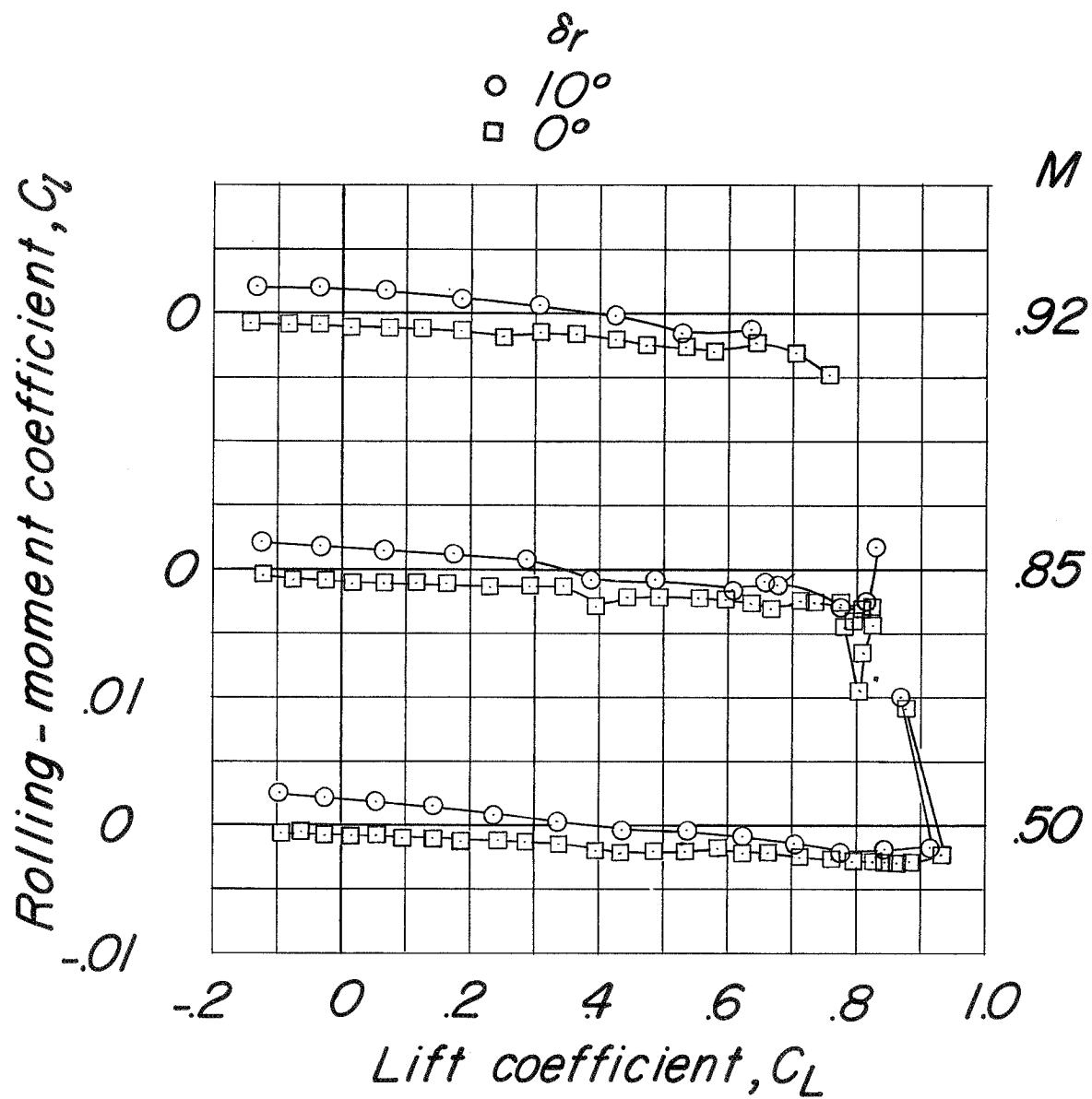
(a)  $C_l$  against  $\alpha$ .

Figure 23.- Aerodynamic characteristics in pitch to determine directional control effectiveness for configuration  $BCW_{F1}V$ ,  $\delta_e = 0^\circ$ .



(b)  $C_l$  against  $C_L$ .

Figure 23.- Continued.

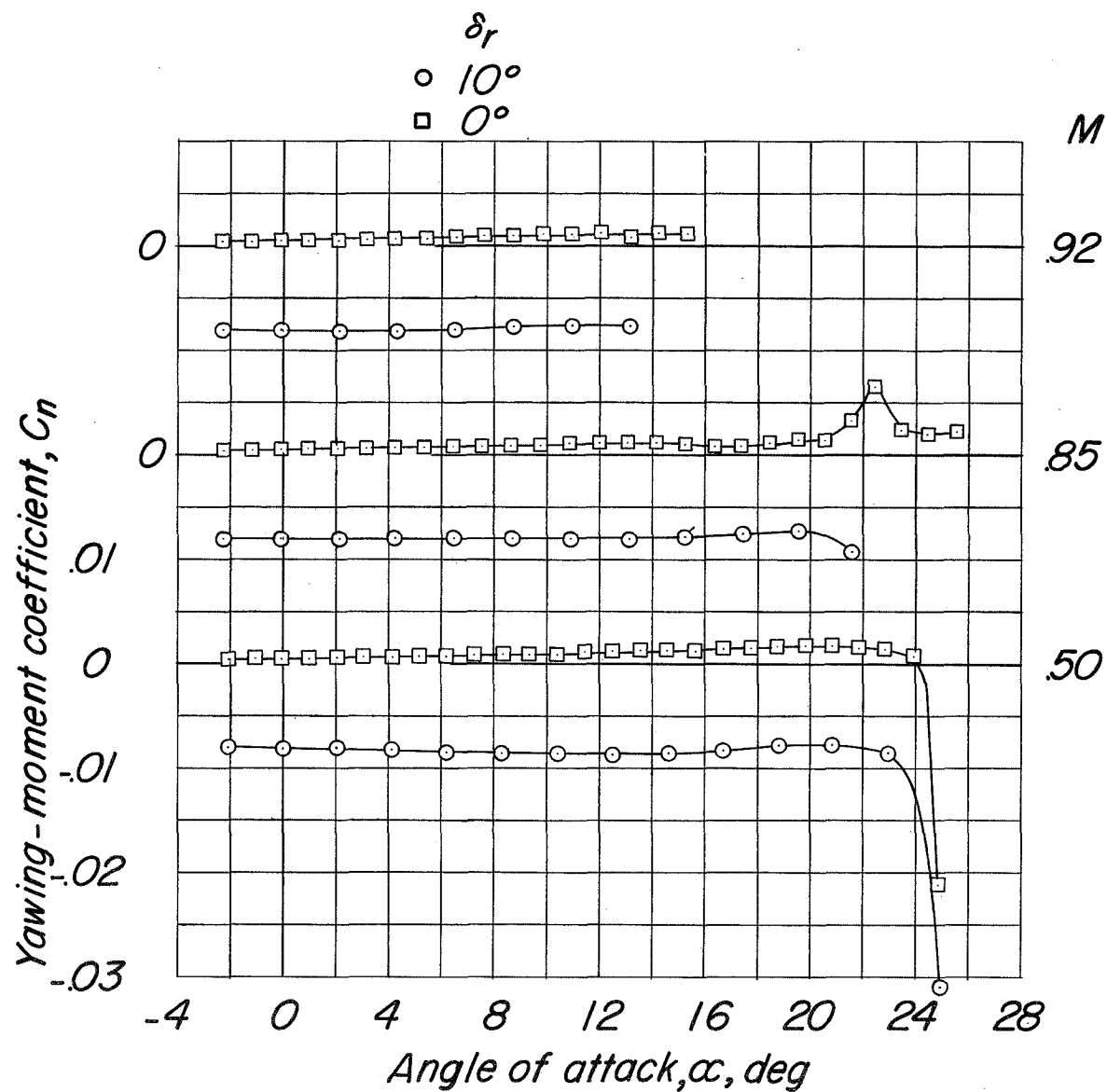
(c)  $C_n$  against  $\alpha$ .

Figure 23.- Continued.

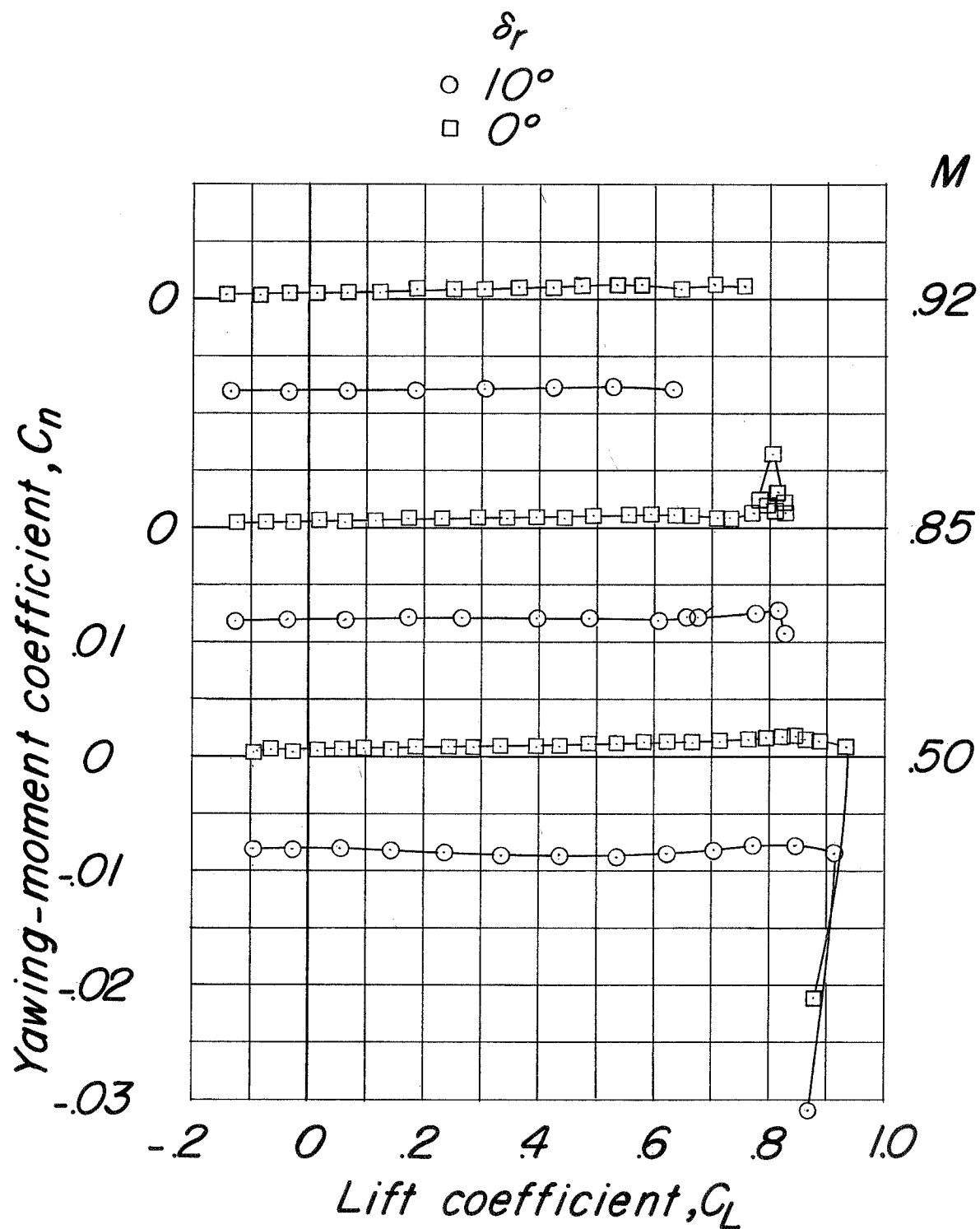
(d)  $C_n$  against  $C_L$ .

Figure 23.- Continued.

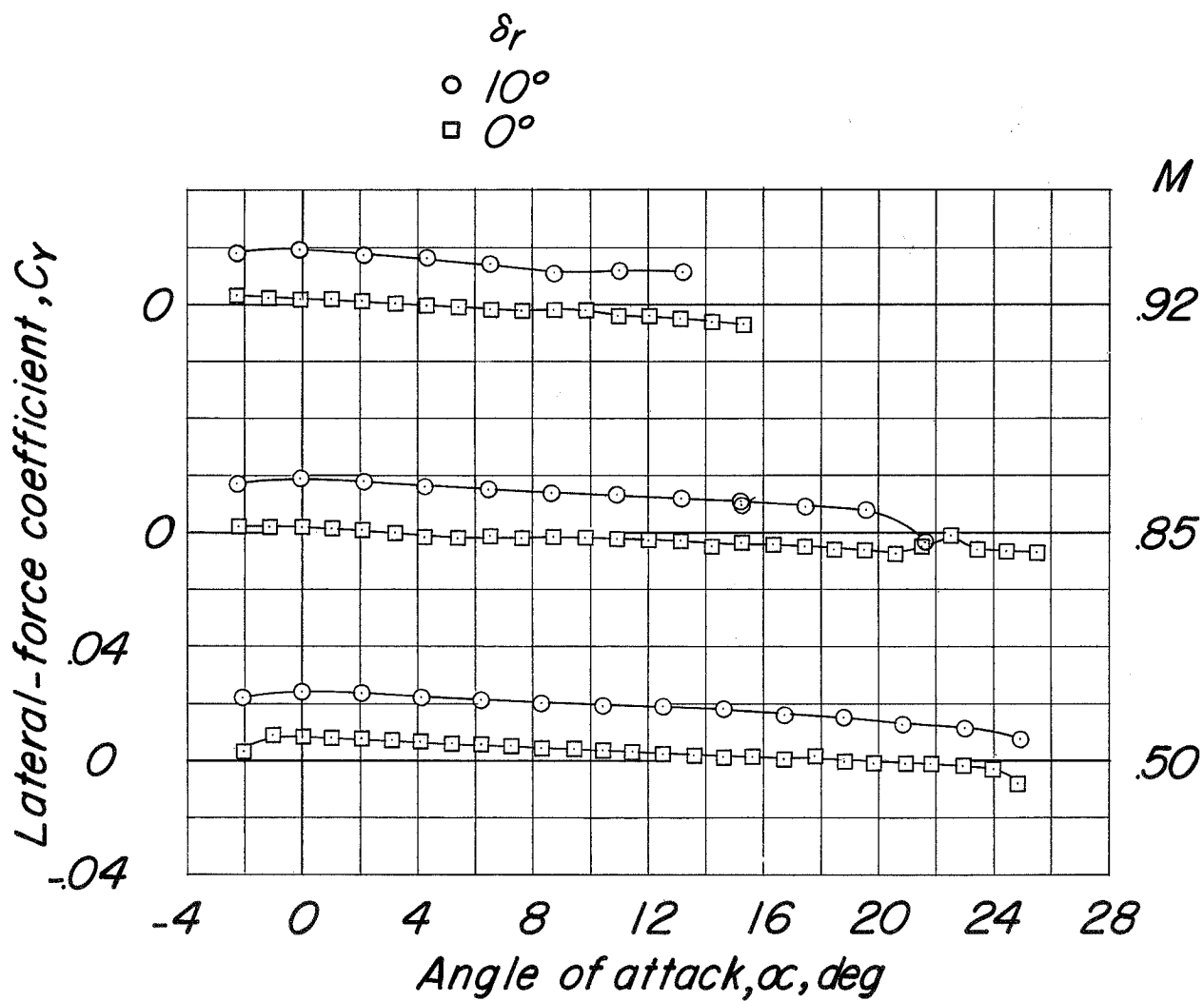
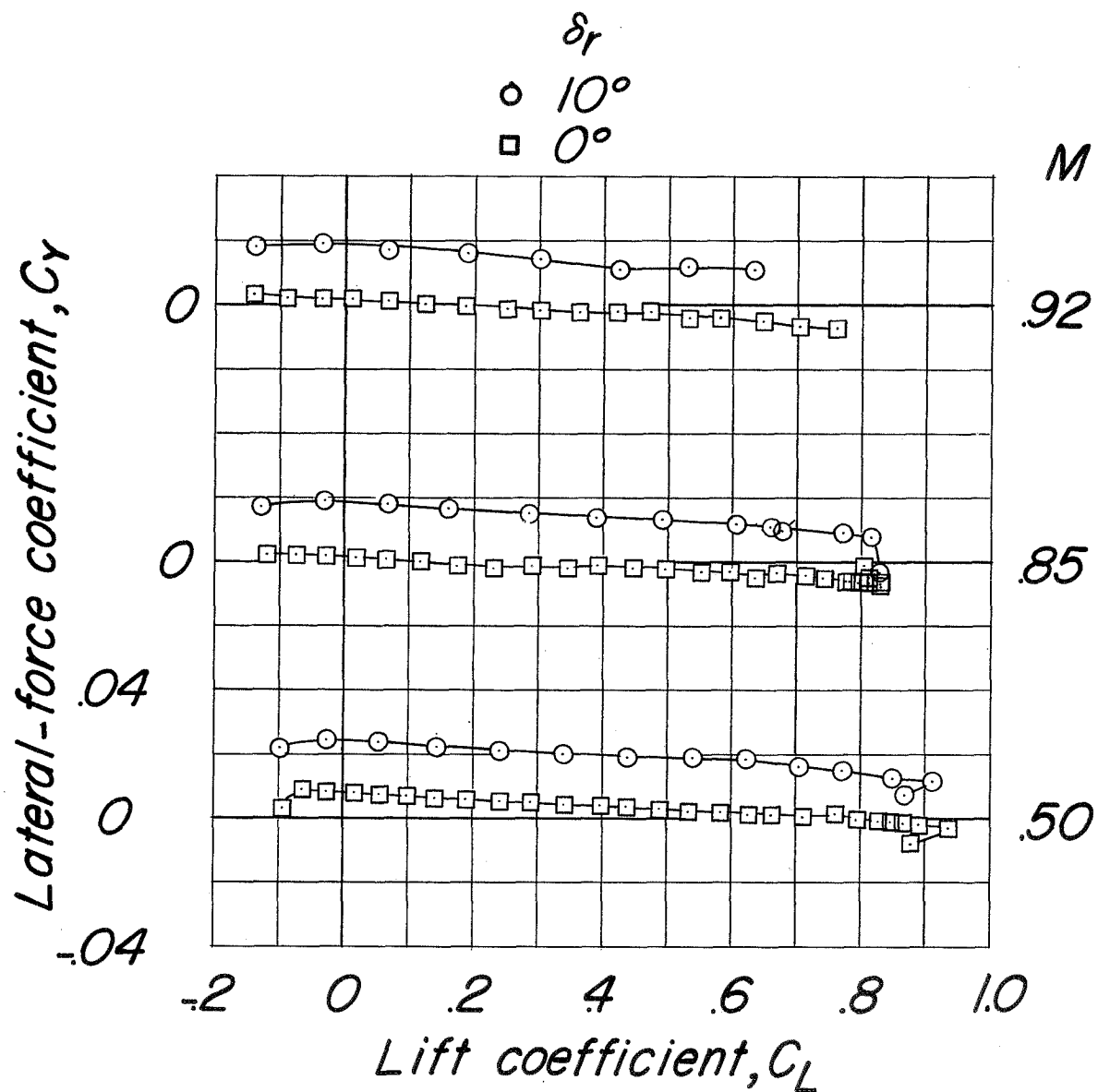
(e)  $C_Y$  against  $\alpha$ .

Figure 23.- Continued.



(f)  $C_Y$  against  $C_L$ .

Figure 23.- Concluded.

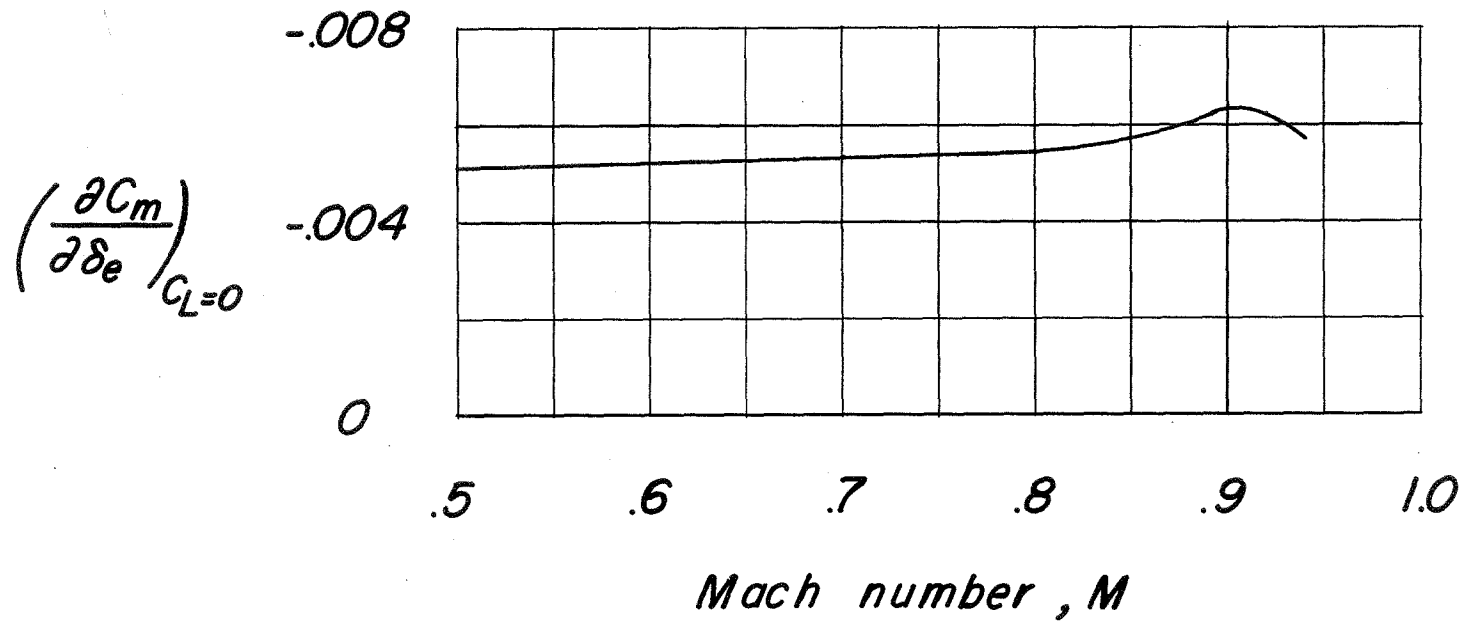


Figure 24.- Elevator effectiveness of configuration BCW<sub>F1</sub>V,  $\delta_r = 0^\circ$ , center of gravity at  $0.30\bar{c}$ .

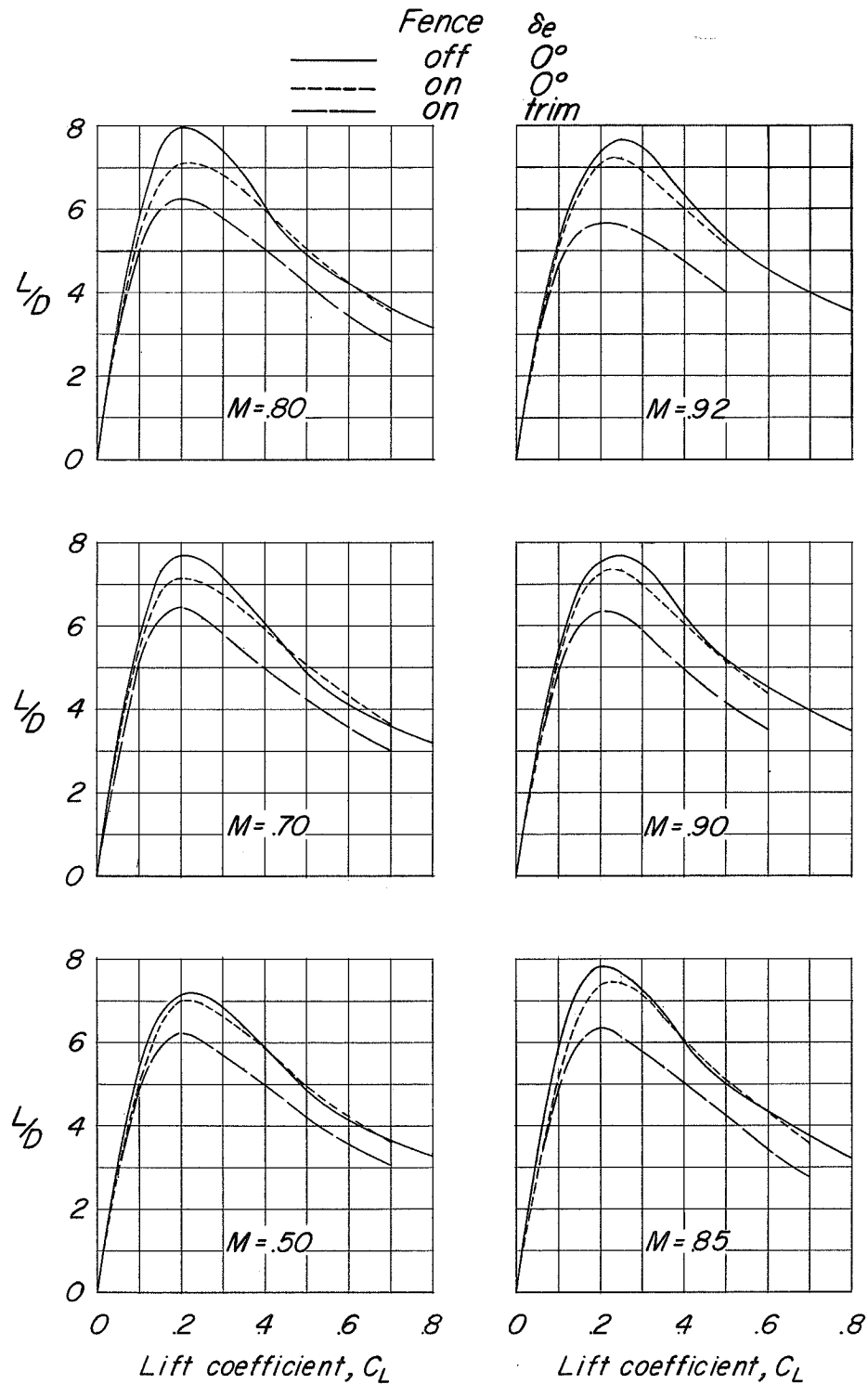


Figure 25.- Lift-drag ratios of configuration BCWV with and without fence 1 and in trim with fence 1,  $\delta_r = 0^\circ$ , center of gravity at  $0.30\bar{c}$ .

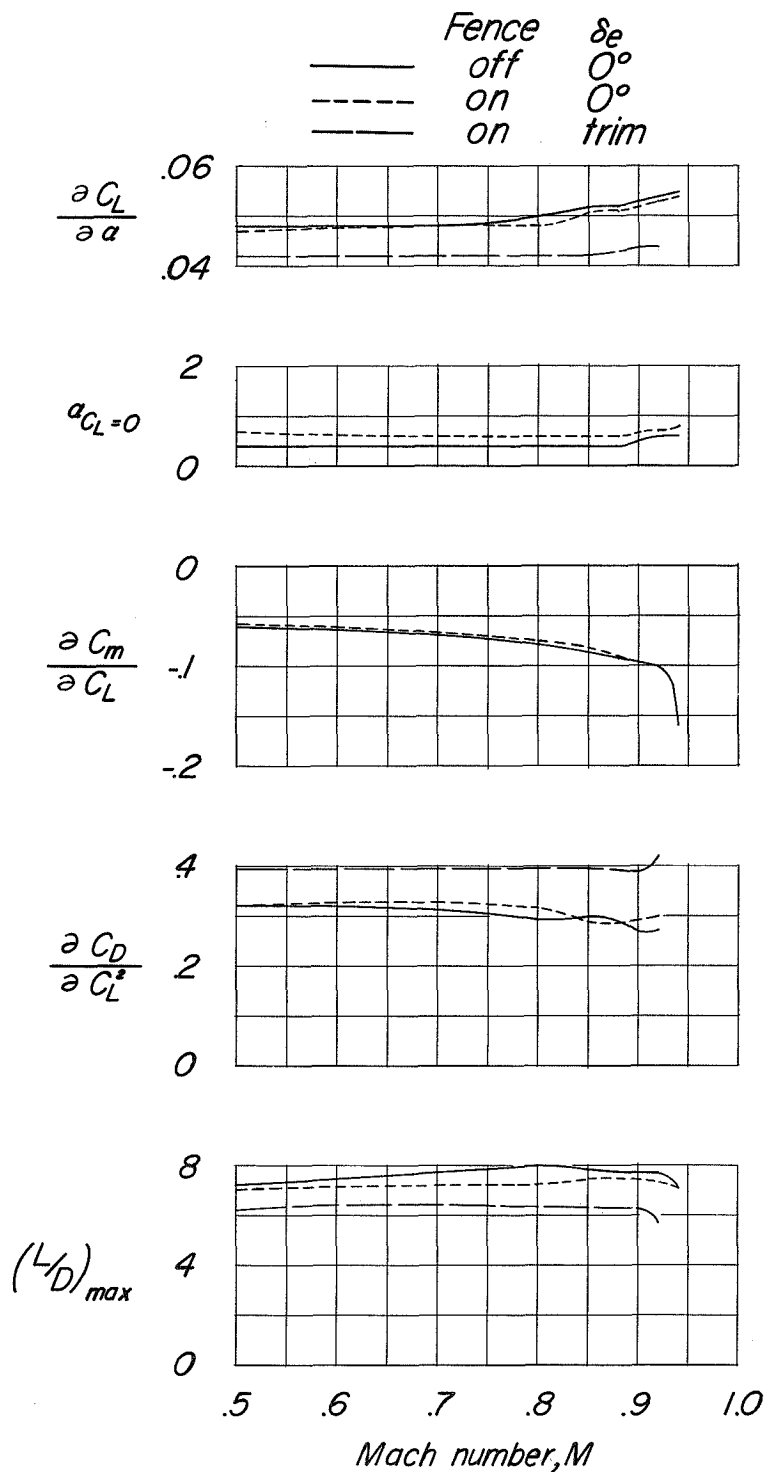


Figure 26.- Summary of aerodynamic characteristics in pitch of configuration BCWV with and without fence 1 and in trim with fence 1,  $\delta_r = 0^\circ$ , center of gravity at  $0.30\bar{c}$ . (Slopes are averaged over lift-coefficient range of 0 to 0.4.)

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